Subjective variables in travel behavior models: a critical review and Standardized Transport Attitude Measurement Protocol (STAMP)

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Abstract
Understanding people's travel behavior is necessary for achieving goals such as increased bicycling and walking, decreased traffic congestion, and adoption of clean-fuel vehicles. To understand underlying motivations, researchers increasingly are adding subjective variables to models of travel behavior. This article presents a systematic review of 158 such studies. Nearly every reviewed article finds subjective variables to be predictive of transport outcomes. However, the 158 reviewed studies include 2864 distinct subjective survey questions. This heterogeneity makes it difficult to reach definitive conclusions about which subjective variables are most important for which transport outcomes. In addition to heterogeneity, challenges of this literature also include an unclear direction of causality and tautological relationships between some subjective variables and behavior. Within the constraints imposed by these challenges, we attempt to evaluate the explanatory power of subjective variables, which subjective variables matter most for which transport choices, and whether the answers to these questions vary between continents. To reduce heterogeneity in future studies, we introduce the Standardized Transport Attitude Measurement Protocol, which identifies a curated set of subjective questions. We have also developed an open-access database of the reviewed studies, including all subjective survey questions and models, with an interactive, searchable interface.

Keywords Attitudes · Perceptions · Travel choice · Travel behavior · Factor analysis

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Introduction

Travel behavior models are used in transportation planning and policymaking to inform decisions including infrastructure spending, land use planning, air quality mitigation planning, and business site selection. Understanding how people make travel behavior choices is necessary for achieving goals such as decreased traffic congestion, adoption of clean-fuel vehicles, and public health improvement through increased bicycling and walking. To understand underlying motivations, researchers increasingly are adding attitudes to the sociodemographics and built environment factors typically used to explain travel behavior.

In a strict psychological sense, attitudes refer to a positive or negative evaluation of a particular object or behavior (Maio et al. 2019, ch.1). In the transport literature, however, attitudes are defined more broadly, and can include true attitudes as well as other constructs such as preferences (Kim et al. 2017; Namgung and Jun 2019), perceptions (Haustein and Jensen 2018; Park and Akar 2019), habits (Atasoy et al. 2013; Namgung and Akar 2015), values (Mokhtarian and Salomon 1997; Xia et al. 2017), beliefs (De Vos et al. 2018; Adnan et al. 2019), perceived social norms (Popuri et al. 2011; Van Acker et al. 2014), perceived behavioral control (Van Acker et al. 2011; Olde Kalter et al. 2020) and lifestyles (Aditjandra et al. 2013; Circella et al. 2017). We adopt this broad view and use "attitudes" as a shorthand for any subjective measure used in travel demand modeling.

There is a large academic literature that incorporates attitudes into models of travel behavior, but no comprehensive review exists to help applied modelers understand how and when attitudes improve predictive power. This article fills that gap. We systematically review this body of literature and identify generalizable findings that can be used by researchers and practitioners wishing to make use of attitudes in their travel behavior models.

We searched the Scopus research database to identify papers for inclusion in this review. We required that "attitudes", "beliefs", or "perceptions" as well as "mode choice", "location choice", "vehicle ownership", or "vehicle type choice" were mentioned in the title, abstract, or keywords. We additionally required that "factor analysis", "principal component analysis", "structural equation", "hybrid choice", "integrated choice", or "latent class" appeared in any field of the article's metadata. The full query appears in Appendix B. We also included a small number of papers that were referenced by the found papers, or that the authors were aware of personally.

Hundreds of candidate articles were identified. The following additional criteria were required for inclusion in this review:

1. The sample size must be 300 or greater.
2. The analysis must include a multivariate model with a transport or residential location choice-related dependent variable, and at least two sociodemographic control variables. While qualitative research into the relationships between attitudes and transport choices is valuable and often forms the basis for later quantitative research, it is not included in this review.
3. The analysis must include either factor analysis or principal component analysis to capture latent attitudes (see Sect. 2). Structural equations and hybrid/integrated choice models are included because a factor analysis is integrated into both of these approaches.
4. The article must not be primarily focused on long distance travel, evacuation travel, autonomous vehicles, or children's travel. These are sufficiently different from general travel behavior that the attitude—travel behavior relationship may differ.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Environmental protection costs too much.	☐	☐	☐	☐	☐
Environmental protection is good for California's economy	☐	☐	☐	☐	☐
Environmentalism hurts minority and small businesses.	☐	☐	☐	☐	☐
People and jobs are more important than the environment.	☐	☐	☐	☐	☐
Stricter vehicle smog control laws should be introduced and enforced.	☐	☐	☐	☐	☐
We should raise the price of gasoline to reduce congestion and air pollution.	☐	☐	☐	☐	☐
Vehicle emissions increase the need for health care.	☐	☐	☐	☐	☐
Using tax dollars to pay for public transportation is a good investment.	☐	☐	☐	☐	☐
We should provide incentives to people who use electric vehicles.	☐	☐	☐	☐	☐
Whoever causes environmental damage should repair the damage.	☐	☐	☐	☐	☐

Fig. 1 Attitudinal statements contributing to the "Pro-Environment" latent attitudinal factor (Kitamura et al. 1997)

The final 158 studies selected for review span the time period from 1981 to 2020. Early foundational papers in this literature were published in the 1990s (e.g., Kitamura et al. 1997), with growth in the literature throughout the 2000s. 130 of the 158 papers in this review were published during the decade between 2010 and 2019.

All of the attitudinal statements, factors, and models in the reviewed articles were entered into a standardized database to allow for easy comparisons between models and to allow researchers to locate prior survey questions and model results. This database is available through an interactive interface at https://files.indicatrix.org/attitudes/.

The next section provides an overview of techniques used in the literature for measuring attitudes. We then discusses key challenges, including both theoretical obstacles and study design challenges. After this, we present main findings, examining whether attitudes are predictive overall and for specific transport choices, as well as geographic variation in the literature. Lastly, we make methodological recommendations for future research and conclude with a research agenda.

Appendix A presents the Standardized Transport Attitudes Measurement Protocol (STAMP), a tool that we developed in conjunction with this review to facilitate standardization of attitudinal measurement in this literature.

Measuring attitudes

The objective of attitude measurement is to obtain a robust metric that captures a person's viewpoint on concepts such as the importance of environmental protection or the convenience of using transit. Standard practice is to ask people's level of agreement with a series of indicator *statements* such as those in Fig. 1. These statements are then combined into attitudinal *factors* using factor analysis or the related technique of principal components analysis.

Attitudinal statements differ from attitudinal factors. Agreement or disagreement with each attitudinal statement is caused by an underlying latent attitudinal factor, which is not directly measured (Van Bork et al. 2017). For instance, an underlying "Pro-Environment" attitude might cause a respondent to agree with "stricter vehicle smog control laws should be introduced and enforced" and disagree with "environmental protection costs too much."

Factors are the preferred method of including attitudinal variables in models of choice, for two reasons. First, factors are the theoretical drivers of choice. Second, attitudinal factors are unlikely to be affected by idiosyncratic responses to individual questions.

Fundamental challenges in the attitude-travel literature

A key finding of our literature review is that there are fundamental challenges that plague interpretation of the relationship between attitudes and travel behavior. The attitudinal statements used rarely overlap between studies, some included attitudes are nearly synonymous with the behaviors they explain, and the direction of causality between attitudes and behavior is unclear.

Heterogeneity in attitude measurement

There is remarkable heterogeneity along three key dimensions of attitudinal measurement in this literature. First, attitudinal constructs are not consistent across studies of particular transport choices. Second, studies use different sets of attitudinal statements to represent seemingly similar attitudinal constructs. Third, there is substantial wording variation even among attitudinal statements that are almost certainly meant to capture the same information. In the 158 papers we reviewed for this study, we identified 2864 distinct attitudinal statements. This heterogeneity makes drawing general conclusions about the relationship between attitudes and travel behavior difficult.

Table 1 demonstrates these concerns. The top rows show two different papers predicting the same outcome with different factors. The middle rows show strikingly different questions associated with a "pro-environment" factor in two different papers, while the bottom rows show how questions about personal identity and public transport can be worded differently.

To promote reproducibility and comparability going forward, we have developed STAMP, a comprehensive instrument for measuring transport-relevant attitudes, which is presented in Appendix A. STAMP draws heavily on previously used questions from the literature and provides a recommended list of attitudinal statements that measure many common transport-related attitudes. Given the breadth of these attitudes, there are 100 questions in this protocol. We do not expect all researchers to use all questions, but rather to choose the questions most relevant to their topics of inquiry.

Unclear direction of causality

There are multiple theoretical constructs that guide the use of attitudinal variables in social science research. By far the most prominent attitude-behavior theory is Ajzen's Theory of Planned Behavior (1991). This construct supposes that choices are influenced by attitudes, defined as positive or negative inclinations toward a certain behavior. However, attitudes are identified as only one of the constructs which determine behavior. The other components of the Theory of Planned Behavior are perceived behavioral control and social norms (both of which might themselves be considered attitudes under the less stringent definition used in travel behavior research). When perceived behavioral control or social norms are a major constraint—say, for expensive international travel or socially undesirable behaviors such as driving under the influence, the importance of one's attitude may diminish. In short, the Theory of Planned Behavior always assumes a causal impact in the direction of attitudes on behavior, but the strength of this relationship may vary.

The competing Theory of Cognitive Dissonance is at times in conflict with Theory of Planned Behavior, postulating that attitudes may in fact be adjusted to be consistent with behavior (Festinger 1962). That is, behavior has a causal impact on attitudes rather than the

Table 1 Heterogeneity in seemingly similar attitudinal factors and statements

Similar outcomes predicted by different attitudinal factors: bicycling		
De Vos et al. (2019)	Gabrhel (2019)	
Pro-car	Landscape	
Pro-walking	Lifestyle	
Pro-cycling	Safety infrastructure	
Similar constructs measured differently: "Pro-environment" factor		
Bagley and Mokhtarian (2002)	Van Acker et al. (2011)	
Environmental protection costs too much. (−)	Car traffic causes serious problems	
Environmental protection hurts minority and small businesses. (−)	I myself can contribute to a solution for traffic problems	
People and jobs are more important than the environment. (−)	It does not matter whether I drive my car or not. Other people still drive their cars. (−)	
Environmental protection is good for the economy	According to family and friends, I should use my car only when absolutely necessary	
Stricter smog control laws should be enforced		
Similar questions with different wording		
Popuri et al. (2011)	Kim and Mokhtarian (2018)	Chen et al. (2017)
I am the kind of person who rides transit	I like the idea of transit as a means of travel for me	I like traveling by taking transit

relationship of the opposite direction proposed by Ajzen. The Theory of Cognitive Dissonance does not reject the causal relationship pointing from attitudes to behavior, but simply provides the reverse as a second plausible pathway for addressing behavior and attitudes which are at odds with each other. Further theories addressing the causal impact of behavior on attitudes have also emerged in recent years (van Wee et al. 2019; De Vos et al. 2021).

Other theories about the attitude-behavior relationship can be found less prominently in the literature. Fishbein's Theory of Reasoned Action is a forerunner to the Theory of Planned Behavior and posits a similar relationship of attitudes influencing behavior (Fishbein 1979). Triandis' theory on values, attitudes, and interpersonal behavior also suggests that attitudes influence behavior, but introduces additional variables such as habits and perceived consequences of an action (Triandis 1979).

Most studies in this literature rely on the Theory of Planned Behavior either implicitly or explicitly for theoretical justification and treat attitudes as independent variables. However, if attitudes are affected by behavior as postulated by the Theory of Cognitive Dissonance, using attitudes as independent variables presents an endogeneity problem. When there is a causal link from the dependent to independent variables, coefficient estimates are biased (Cameron and Trivedi 2005, p. 92). Endogeneity problems also make it difficult to understand the effects of attitude changes on travel behavior (Chorus and Kroesen 2014; Kroesen and Chorus 2018).

An increasing number of studies note the potential for a bidirectional relationship (Wang and Chen 2012; de Abreu e Silva 2014; Lin et al. 2017; Moody and Zhao 2019; Barajas 2019), with some studies explicitly finding that behaviors influence attitudes more strongly than attitudes influence behaviors (Kroesen et al. 2017; van de Coevering et al. 2021). The direction of causality likely depends on the attitude. For example, an attitude such as "It is inconvenient to commute without a car"[1] is likely influenced by past commuting experience; the influence of behavior on attitude may be dominant here. However, other attitudes may be more likely to influence travel behavior than to be influenced by travel behavior. For instance, "I am concerned about global warming" may influence travel behavior, but be less influenced by past travel experiences. Many attitudes included in this literature probably have a bidirectional relationship with behavior.

Most research on how attitudes affect travel behavior use cross-sectional data. Cross-sectional studies show correlations, but longitudinal studies are the best way to examine causal relationships (Chorus and Kroesen 2014). While this is a challenge with many variables used in travel behavior models, it is especially salient with research on attitudes due to the lack of a clear theoretical argument for one direction of causality over the other (Kroesen and Chorus 2018). Future research on attitudes should use longitudinal samples whenever possible.

Self-evident attitudinal relationships

Many studies include explicit preferences *about the transport choice being modelled* among the attitudinal constructs used to predict that transport choice. For instance, car use might be modelled with a factor partly based on the statement "I like driving" (Handy et al. 2005; e.g., Ettema and Nieuwenhuis 2017). Unsurprisingly, this statement tends to

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[1] Unless otherwise indicated, attitudinal statements used as examples are drawn from STAMP; see Appendix A for citations to the original sources.

be a strong predictor of driving. This relationship is intuitively obvious, however, and the strength of this predictor will mask the potentially more interesting relationships (i.e. factors that cause a person to both like driving and use a car). Furthermore, these types of attitudes are likely endogenous, partially caused by engaging in the behavior in question.

Findings

This review includes 158 papers from the travel behavior literature. We first establish that attitudinal data improve travel behavior models and discuss the limitations of this conclusion. We then review the different types of attitudes found in the literature and their relevance for different travel outcomes. Finally, we examine the global distribution of papers as well as how findings differ between continents.

How important are attitudes for predicting travel behavior?

Our review indicates that attitudes play an important role in travel decisions. In fact, some papers find that attitudes have stronger relationships with certain travel outcomes than sociodemographics (Belgiawan et al. 2016) or the built environment (Kitamura et al. 1997; Kamruzzaman et al. 2013; de Abreu e Silva 2014; Ye and Titheridge 2017). The most convincing evidence for the importance of attitudes comes from researchers who perform their full analyses twice, either once with attitudes and once without, or once with only attitudes and once with all explanatory variables.

Table 2 summarizes key aspects of 12 studies that perform this explicit comparison, representing 34 models. It is difficult to draw generalized conclusions from this set of studies beyond a strong consensus that attitudes matter. Each study uses a unique combination of dependent variables, demographic controls, attitudes, and estimation methods, and results regarding the level of importance of attitudes are uneven across studies. Thus, it remains unclear which attitudes matter most, and for which transportation choices.

While the contribution of attitudes to goodness-of-fit is only quantifiable when two models are estimated, we can evaluate whether attitudinal factors were statistically significant in papers without a comparison model. Of the literature reviewed here, only 2 out of 158 papers did not find attitudes to be significant anywhere in their research (Kamruzzaman et al. 2016; Ding et al. 2017), while two did not report the significance of latent attitudes in their models (Giles-Corti et al. 2013; Kroesen 2019). Even though significant results may be more likely to be published (Rothstein et al. 2005), the sheer volume of statistically significant attitudes suggests that they are important predictors of transport choices.

This seemingly overwhelming evidence might be misleading, however. Most articles evaluate multiple attitudinal factors, and test them in multiple models, which can lead to multiple-testing bias—where some explanatory variables are statistically significant purely by chance, due to the large number of tests conducted (Dmitrienko et al. 2009). This is exacerbated by the practice of removing insignificant variables from final models without noting which variables were removed, making it impossible to apply correction factors for multiple testing.

In light of this issue, we conducted the following analysis to conservatively evaluate the statistical significance of attitudinal factors. We assumed that if an attitudinal factor was created in a factor analysis, it was tested in every model in a paper, excluding models

Table 2 Contribution of attitudes to predictive power, selected papers

Paper	Model type	Attitudes	Demographics	Outcome	FIT metric	Full model	W/O ATT	Only ATT
Akar and Clifton (2009)	Multinomial logit	Safety, fitness	G, CR	Commute mode choice	adj. ρ^2	0.30	0.30	
Cao et al. (2009b)	Seemingly unrelated regression	Travel liking, neighborhood preferences, safety, pro-NMT, pro-transit	A, I, G, E, C, ES, CO, bicycle owner, DL, limitations	nonwork car use frequency	adj. R^2	0.09	0.06	
				Nonwork transit use frequency	adj. R^2	0.15	0.11	
				Nonwork NMT use frequency	adj. R^2	0.47	0.30	
Haustein and Jensen (2018)	Ordinary least squares	charging convenience, EV social norm, EV image, pro-EV, EV pro-environment, EV price satisfaction	A, I, G, E, C, HH	SP intention to use BEV (CV owners)	adj. R^2	0.57		0.56
				RP use (EV owners)	adj. R^2	0.42		0.41
Kitamura et al. (1997)	Ordinary least squares	pro-environment, personality, neighborhood preferences, automotive mobility, pro transport control measures, pro-transit	A, I, E, HH, # adults, CO, DL	# trips	R^2	0.17	0.14	
				# transit trips	R^2	0.21	0.15	
				# NMT trips	R^2	0.09	0.03	
				% car trips	R^2	0.21	0.14	
				% transit trips	R^2	0.19	0.13	
				% NMT trips	R^2	0.13	0.07	
Kuppam et al. (1999)	Multinomial logit	convenience, performance	I, C, CO, ES	Commute mode choice	adj. ρ^2	0.57	0.49	0.53
Namgung and Akar (2015)	Binary logit	safety, convenience, comfort, social norm, pro-car	G, CR, ethnicity	Commute by transit or not	ρ^2	0.27	0.15	
Park and Akar (2019)	Binary probit	safety, convenience, comfort, image	G, CR	Commute by bicycle or not	Log-Pseudo Likelihood	(117.34)	(196.58)	

Table 2 (continued)

Paper	Model type	Attitudes	Demographics	Outcome	FIT metric	Full model	W/O ATT	Only ATT
Schwanen and Mokhtarian (2005a)	Multinomial logit	pro-environment, personality	A, I, G, O, CO/DL, number of workers	Commute mode choice	adj. ρ^2	0.27	0.26	
Van Acker et al. (2011)	Factor analysis + structural equation "path models" that include factor scores as independent variables	Pro-environment, personality, neighborhood preferences, comfort	G, CO, family type	car choice, active leisure trips	R^2	0.62	0.17	
				transit choice, active leisure trips	R^2	0.24	0.16	
				NMT choice, active leisure trips	R^2	0.30	0.10	
				car choice, family visits	R^2	0.22	0.24	
				transit choice, family visits	R^2	0.62	0.46	
				NMT choice, family visits	R^2	0.18	0.10	
				car choice, fun shopping trips	R^2	0.80	0.49	
				transit choice, fun shopping trips	R^2	0.50	0.30	
				NMT choice, fun shopping trips	R^2	0.50	0.30	
Verma et al. (2018)	Binary logit	Convenience	I (A, G, O not statistically significant and not in models presented)	switch to cycling for commute (part-time cyclists)	ρ^2	0.11		0.10
				Switch to cycling for commute (non-cyclists)	ρ^2	0.14		0.11

Table 2 (continued)

Paper	Model type	Attitudes	Demographics	Outcome	FIT metric	Full model	W/O ATT	Only ATT
Wang et al. (2018)	Ordinary least squares	Pro-environment, convenience, performance, social norm	A, I, G, E	Intention to use public (shared) bicycles	adj. R^2	0.51	0.03	
Wolday et al. (2019)	Ordinary least squares	Neighborhood preferences	A, I, G, E, C, DL	Commute distance	adj. R^2	0.28	0.24	
				weekly non-work car VKT	adj. R^2	0.11	0.11	
				car % total weekly distance Traveled	adj. R^2	0.30	0.24	
				transit % total weekly distance traveled	adj. R^2	0.14	0.05	
				NMT % total weekly distance travelled	adj. R^2	0.26	0.22	

A = age, I = income, G = gender, O = occupation, E = educational attainment, C = children, HH = household size, ES = employment status, CO = car owner, DL = driver's license, CR = campus role (student, faculty, etc.)

NOTE: Hybrid choice or integrated choice and latent variables (ICLV) models are not included in this table because the fit metrics are not directly comparable between model formulations with and without attitudes (Kløjgaard and Hess 2014)

specifically marked as comparison models without attitudes. We then recorded how many significant attitudinal factors (at the $p < 0.05$ level) were reported in every individual model.[2] We estimate that attitudinal factors were entered into models 2621 times in our selection of literature and were found significant 1195 times. This back-of-the-envelope calculation allows us to conservatively estimate that attitudes are statistically significant in models of transport choices 46% of the time.

Some papers include many attitudes, exacerbating multiple testing concerns. When we remove papers that identify more than 10 attitudinal factors in their factor analysis (about 20% of papers in this review), we find that the rate of significance for attitudes increases to 54%.

These statistics show that attitudes are more often than not significant predictors of transport choices. When a small number of attitudes is carefully selected based on theoretical relationships with the transport choice of interest, statistical significance is more likely than not.

In some cases, attitudinal variables may be proxying for standard sociodemographic variables that are not included. Unfortunately, 34% of papers do not control for income in their models, 24% do not control for gender, 18% do not control for age, and 54% do not control for household size.

Nevertheless, it is clear that attitudes contribute to the predictive ability of models of transport choices. Improved methodologies such as performing analyses with and without attitudes, including sociodemographics in models, using small, theoretically justified sets of attitudes, and reporting insignificant coefficients will improve estimates of the relationships between attitudes and transport choices.

Which attitudes are most relevant for predicting different transport choices?

Not every transport-related attitude is likely to be predictive of every transport-related choice. To develop surveys that capture the information needed to address particular research or policy questions, it is important to know which attitudes are most relevant for which transport choices. This section analyses which types of attitudes have been successfully used to model five major transport-related choices: mode choice, vehicles miles traveled, residential location choice, vehicle ownership, and vehicle type choice. This will be useful to modelers deciding which questions from STAMP (Appendix A) will be useful in their models.

Mode choice

In the reviewed literature, attitudes are most often used in models of mode choice. There are two primary reasons researchers include attitudes in these models. Many directly evaluate the relationships between attitudes and mode choice. Others use attitudes to control for residential self selection—that is, whether people choose to travel in a particular way due to neighborhood built environment, or whether they choose neighborhoods based on how

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[2] In cases where a structural equation model is specified so that an attitudinal factor has a direct effect on multiple dependent variables, the attitude is counted as significant if any of its effects on dependent variables in that model are significant, or there is a pathway to the dependent variable consisting of only significant effects. Excluding papers that fit structural equation models leads to a slightly lower significance rate (41%).

they prefer to travel (Cao et al. 2009a; Lin et al. 2017). The goal of these studies is not to estimate the extent to which attitudes predict mode choices, but to reduce bias in estimates of the relationship between mode choices and the built environment (Aston et al. 2020b). There are a few studies—notably Kitamura et al. (1997)—that aim to do both.

Mode liking

An oft-used and highly predictive attitudinal factor is the attitude towards the mode of interest. Attitudinal statements are often as simple as "I like walking" (e.g., Cao et al. 2009b; Guan and Wang 2019). Unsurprisingly, positive attitudes towards a mode are associated with increased likelihood of using the chosen mode and decreased likelihood of choosing other modes (Handy et al. 2005; Cao et al. 2007; Maldonado-Hinarejos et al. 2014; Ettema and Nieuwenhuis 2017; De Vos et al. 2018). As discussed earlier, including them in predictive models introduces concerns about endogeneity and may render more important relationships insignificant.

Environmentalism Environmental concerns are another prevalent predictor of mode choice. People who are more concerned about the environment are more likely to choose sustainable modes, such as walking, biking, and public transportation, as opposed to driving (Kitamura et al. 1997; Mokhtarian et al. 2001; Schwanen and Mokhtarian 2005a; Etminani-Ghasrodashti and Ardeshiri 2015; Kim et al. 2017; Roberts et al. 2018). However, some researchers have suggested that this attitude is often less important than other motivators such as comfort or convenience (Geng et al. 2017).

Comfort Many surveys report that comfort is an important motivator for mode choice, particularly for public transit use (Vredin Johansson et al. 2006; Hu et al. 2015; Ababio-Donkor et al. 2020). Comfort encompasses a broad array of questions, from "public transport is comfortable" to "privacy is important to me when choosing how I get around" to "driving is stressful". Questions about comfort are often specific to a mode.

Convenience Convenience can be a strong predictor of behavior—people tend to choose modes that are convenient, given their abilities and geographical context. Examples of the types of questions in this category include "bicycling is fast for local trips," "it is inconvenient to commute without a car," and "public transport is conveniently located to most of my destinations." Questions about convenience are usually specific to a mode.

Many convenience questions refer to perceptions of transport options and the built environment. People who agree with "There are bike lanes easy to access in my neighborhood" are likely to also bicycle more (Park and Akar 2019). People who perceive that there is "no public transit where [they] live" are more likely to drive more (Habib and Zaman 2012). Perceived transport and built environment measures capture personal characteristics and attitudes that relate to mode convenience and safety that objective measures do not (e.g., comfort riding a bike alongside traffic). Objective measures are generally preferred in practice, but future research should explore when and how perceptions deviate from reality.

Safety Safety is another attitude that is often included in models of mode choice. Sometimes, surveys ask generally about safety (Cao et al. 2006, 2009b; Xia et al. 2017; Ye and Titheridge 2017; Gabrhel 2019; Guan and Wang 2019). Others specifically ask about traffic safety (Kuppam et al. 1999; Popuri et al. 2011; Adams et al. 2013; Noland and

Dipetrillo 2015), personal safety from crime (Kuppam et al. 1999; Parra et al. 2011), security from bicycle theft (Namgung and Jun 2019; Park and Akar 2019), or the presence of infrastructure for safety (Giles-Corti et al. 2013; Lee 2013; Acheampong and Siiba 2018; Sottile et al. 2019). Questions about safety are almost always specific to a particular mode, usually active travel. Perceiving active modes as safe is generally associated with increased usage, but one study (Gabrhel 2019) found the opposite—possibly because people who do cycle are more aware of the safety concerns present on the road.

Self-image Although practical concerns such as convenience, comfort, and safety are important predictors of mode, this choice is also dependent on more subjective perceptions. Europeans in particular are more likely to bicycle if they self-identify with bicycling or see it as socially desirable (Lois et al. 2015; Barberan et al. 2017a; Ramezani et al. 2018). In a similar way, North Americans who pride themselves on being car owners or enjoy the status of driving tend to own more cars and use them more heavily relative to other modes (Schwanen and Mokhtarian 2005a; Haustein and Jensen 2018; Moody and Zhao 2019).

Residential preferences Some studies of mode choice include attitudinal constructs that measure preferences about neighborhood type or built environment characteristics (Kitamura et al. 1997; Etminani-Ghasrodashti et al. 2018b, a). These may be relevant to mode choice outcomes because people who hold these preferences may tend to choose to live in neighborhoods where certain modes are more or less accessible.

Habit Habits can play a strong role in decisionmaking, especially for day-to-day decisions that are made rapidly (Triandis 1979; Kahneman 2011). Evaluating the role of habit using revealed-preference data can be difficult, however; it is hard to know if repeated behaviors are due to habits or unobserved contributors to the decision that do not vary over time. Attitudes can improve on this situation by asking respondents directly about their habits, as opposed to inferring them from behavior. For instance, Ramos et al. (2020) include a "driving habit" factor in their models, including questions such as "using a car is something I don't need to thing about" and "using a car is a part of my routine." They find this factor to be predictive of trip frequency for a variety of purposes. Even more so than with other attitudes, however, bidirectional causality is a concern with habits—habits are the result of past choices. Even habits measured using attitudinal statements may reflect other unmeasured factors that influenced these past behaviors, and may continue to influence current behavior.

Vehicle miles traveled

Vehicle miles or kilometers traveled is the subject of a small number of papers. This outcome tends to be predicted by many of the same attitudes that also predict mode choice, especially mode-liking (Handy et al. 2005; Cao et al. 2007; Frank et al. 2007; Aditjandra et al. 2010; Banerjee and Hine 2016; Circella et al. 2017; Chen et al. 2017), residential preferences (Schwanen and Mokhtarian 2005a; Cao et al. 2007; Aditjandra et al. 2010; Ewing et al. 2016; Jamal et al. 2017), and environmentalism (Golob and Hensher 1998; Schwanen and Mokhtarian 2005a; Jamal et al. 2017; Circella et al. 2017). One unique predictor of vehicle miles or kilometers traveled is a general (dis)like of travel (Cao et al. 2007; Jamal et al. 2017; Chen et al. 2017).

Residential location choice

Residential location choice is considered a transport-related choice because the characteristics of one's residential environment have a consistent, well-documented effect on travel choices (Cao et al. 2009a; Ewing and Cervero 2010; Salon et al. 2012; Guan et al. 2019; Aston et al. 2020a).

Preference for access One major predictor of residential location choice is a preference for access, with questions such as "having shops and services within walking distance of my home is important to me" and "I would like a neighborhood with easy access to public transport service". In general, preferences for both overall accessibility and access to specific locations like health clinics and shops are associated with living in city centers or walkable, transit-accessible neighborhoods (Berkoz et al. 2009; Chen et al. 2017; Wolday et al. 2018, 2019; Guan and Wang 2019). However, Wolday et al. (2018) found that preferences for access to some locations, such as shopping malls and outdoor exercise facilities, have a negative association with living in these neighborhoods, presumably because of the prevalence of these destinations in suburban areas.

Mode liking As discussed in above, attitudes such as "pro-biking" or "pro-car" are most often used in models of mode choice. However, these questions are also common predictors of residential location choice, and do not present the same concerns about self-evident relationships that they do in mode choice models. Having a "pro-car" or "pro-driving" attitude is associated with living in less accessible areas or neighborhoods further from the city center (de Abreu e Silva 2014; Phani Kumar et al. 2018; Guan and Wang 2019), while preferences for active travel or public transit are associated with the opposite (de Abreu e Silva 2014; Chen et al. 2017; De Vos et al. 2019). However, these attitudes are often insignificant in residential location choice models, despite being justified theoretically.

Closely related to modal preferences is a desire for transit access. Usually defined as a preference for nearby transit infrastructure such as bus stops or train stations, this attitude is also positively correlated with residence in central neighborhoods (Cao and Ermagun 2017; Chen et al. 2017; Wolday et al. 2018, 2019).

Neighborhood social aspects Two less common predictors of residential location choice are the social features and family friendliness of a neighborhood. Wolday et al. (2018, 2019) found that the desire to live near family and friends was associated with a lower likelihood of moving to or living in a transit-rich neighborhood. However, one study has found an association between residence in urban areas and a preference for socializing opportunities within the neighborhood (Chen et al. 2017). The effect of a preference for family-oriented neighborhoods is more consistent in the literature: the desire for either a child-friendly neighborhood in general or specific characteristics such as a private backyard tend to decrease the likelihood of choosing to live in a transit-rich neighborhood (Wolday et al. 2018, 2019).

Vehicle ownership

Convenience Individuals who perceive car travel as convenient are more likely to own or purchase a car (Belgiawan et al. 2016; He and Thøgersen 2017). However, individuals who see cars as *solely* functional tools are less likely to own them (Zhou and Wang 2019), likely

because other motivations for car purchase such as social value or enjoyment of driving do not factor into these individuals' decisions.

Residential preference Residential preferences play a significant role in car ownership, with a preference for accessible, dense neighborhoods being correlated with lower rates of car ownership (Ewing et al. 2016; Kim and Mokhtarian 2018), possibly because these people choose to live in neighborhoods where non-car travel is more convenient.

Perception of alternative modes

An important predictor of car ownership is one's perception of alternative modes, especially public transport (Ho and Yamamoto 2014; Belgiawan et al. 2016; He and Thøgersen 2017; Kim and Mokhtarian 2018). These studies found that viewing public transport unfavorably was usually associated with higher rates of car ownership. Car-dependence attitudes, in which respondents feel they cannot get around well without a car, are predictive of car ownership as well (Belgiawan et al. 2016; Ao et al. 2019a).

Vehicle type choice

Two classes of dependent variables are generally used in models of vehicle type choice. Some studies examine the relationship between attitudes and the vehicle body type that a respondent prefers, such as an SUV, sedan, or sports car. This literature is small and heterogeneous, with few well supported conclusions. One observable trend is that purchasers of luxury and sports cars tend to be more concerned with social status (Choo and Mokhtarian 2004; Mohamed et al. 2018; Tsouros and Polydoropoulou 2020).

A second category of studies are primarily interested in what vehicle fuel type a respondent prefers, such as gas, electric, or biodiesel. Environmental concern is by far the attitude most frequently used to predict purchase or ownership of alternative fuel vehicles (Sangkapichai and Saphores 2009; Jensen et al. 2013; Daziano and Bolduc 2013; Kim et al. 2014; Mohamed et al. 2016, 2018; Haustein and Jensen 2018; He et al. 2018; Nie et al. 2018; Soto et al. 2018; Ghasri et al. 2019; Liu et al. 2019; Xu et al. 2019; Tsouros and Polydoropoulou 2020). Enjoyment of new technologies (Kim et al. 2014; He et al. 2018; Soto et al. 2018; Tsouros and Polydoropoulou 2020), a concern for the social value of electric vehicles (Mohamed et al. 2016, 2018; Haustein and Jensen 2018; He et al. 2018; Xu et al. 2019; Tsouros and Polydoropoulou 2020), and perceived costs or savings (Kim et al. 2014; He et al. 2018; Huang and Ge 2019; Xu et al. 2019) are common predictors as well. Perceived behavioral control presents a major barrier to electric vehicle adoption. Electric vehicles are less popular among those who are sensitive to operational hassles such as long charging times, difficulty finding charging stations, or short battery life (Kim et al. 2014, 2015; Mohamed et al. 2016, 2018; Haustein and Jensen 2018; He et al. 2018; Ghasri et al. 2019; Huang and Ge 2019; Xu et al. 2019).

How does the attitude-travel behavior research vary by geography?

Although research on attitudes and travel behavior spans the globe, the geographic distribution of studies is uneven. Table 3 shows the geographic distribution of the studies we reviewed. It also shows what percentage of the papers in each region cover particular topics

Table 3 Overview of studies reviewed and topics covered by geography

Continent	Number of Studies	Mode choice (%)	Residential location choice (%)	Vehicle ownership (%)	Vehicle type (%)
Europe	65	74	11	6	9
North America	48	75	8	15	12
East Asia	23	65	13	57	26
Australia	10	70	20	0	10
India	4	75	25	25	0
Middle East	4	100	0	0	0
South America	3	67	0	0	33
Africa	1	100	0	0	0
All	158	73	11	16	13

(one paper may cover multiple topics). Despite differences in focus, studies in all regions find attitudes to be significant.

Europe and North America are both overrepresented in the literature, with each represented in more studies than all other regions combined. Even within these regions, most studies focus on western Europe and the United States. Asia is also fairly well-studied, although biased toward East Asia. India, Australia, the Middle East, and the global South are underrepresented in this literature. Therefore, the conclusions reported in this review apply primarily to Europe, North America, East Asia, and, to a lesser extent, Australia.

Differences by geography do appear in Table 3. Some of these are due to differing contexts between regions. Vehicle ownership is much more heavily studied in East Asia than in other contexts (Kim et al. 2015; Verma et al. 2016; He and Thøgersen 2017; Guan and Wang 2019). This is likely a result of the rapid motorization that Asia is currently undergoing (Wang et al. 2012).

Rural mobility is also more studied in Asia than Europe or North America (Ao et al. 2019a, b), probably because this region is still urbanizing. Bicycling is heavily studied in Europe, likely due to relatively high cycling mode share (Buehler and Pucher 2012).

Other differences appear to result from idiosyncratic differences in the interests and professional networks of researchers in various regions. For example, relocation studies that exploit residential moves to isolate the effects of attitudes and the built environment are more common in Europe, whereas a significant body of North American research investigates residential self-selection and travel behavior using attitudinal variables.

Few studies have been replicated in different geographic contexts, making direct comparisons of the effects of attitudes on travel difficult. Exceptions include Aditjandra et al. (2010), who replicated Handy et al.'s (2005) US study in the UK, finding that built environment measures were significant predictors of travel behavior even after controlling for travel attitudes in the UK, whereas they were not in the US. Van et al. (2014) conducted a survey in six East Asian countries, and found that in less developed countries, the perception of social orderliness of public transport was a strong motivating factor for public transport use, whereas in more developed countries, instrumental/utilitarian factors were more important. We recommend that more researchers replicate studies across geographic contexts to allow for these types of comparisons. Relying on STAMP will help make research comparable across geographies.

Methodological suggestions

Reducing heterogeneity in attitudinal questions

A major obstacle in the literature is widespread heterogeneity in attitudinal statements used by different researchers. This is a barrier to drawing conclusions from the body of research as a whole. Our contribution is the development of STAMP (Appendix A), a list of recommended attitudinal questions that capture the major constructs investigated in this literature. Most questions in STAMP are sourced directly from existing work or are only lightly modified, so the majority of the protocol has already received some validation. We encourage drawing questions from STAMP in survey development, allowing attitudes to be compared across studies.

Selecting theoretically defensible attitudes

Most studies in this literature are based on the Theory of Planned Behavior (Ajzen 1991), although this theory is somewhat intuitive and so widespread in the literature that it does not always receive a direct citation. Regardless of whether authors discuss the psychosocial theories which underpin their work, they should ensure that the attitudes they select have a theorized causal link with travel outcomes. Most but not all papers clearly establish the theoretical relevance of their attitudinal variables to the outcome variable.

We advise against the use of "mode-liking" questions on surveys to predict mode choice. These questions introduce bias, obscure more important results, and at best capture relationships that are already well-established and relatively intuitive. As a caveat to this recommendation, however, we note that these questions are often worth including when the outcome variable of interest is not mode choice.

Often, researchers include many attitudinal factors in their models. However, this leads to concerns about multiple-testing bias. The inclusion of attitudes without theoretical justification also contributes to concerns about endogeneity, since the direction of causality is not theoretically clear in these cases. We recommend researchers use a smaller number of theoretically justified attitudinal factors in their models.

A common problem with the questions in this literature is that they use the word "travel" to refer to daily transportation. While this meaning is common in a research context, to the general public the word "travel" generally refers to long-distance travel. For this reason, we recommend that researchers avoid this wording, and we have avoided it in STAMP.

Statistical methodology

To clarify the contribution of attitudes to predicting travel behavior, we recommend that all researchers include sociodemographic controls *and* perform their analyses twice, once with only the sociodemographic controls and once with both sociodemographics and attitudes. This is the only way in which the contribution of attitudes to a model's predictive power can be understood. The inclusion of a complete set of sociodemographics ensures that variation in the data attributable to observable characteristics is not assigned to attitudes.

We also strongly recommend against the use of stepwise regression, also known as best subset selection, a technique in which explanatory variables are introduced into or removed from a model in stages, with only the most significant ones being retained. This practice

can distort results, make significance tests unreliable, and result in models that lack theoretical justification (Thompson 1995).

Less egregious but far more common than stepwise regression is the removal of statistically insignificant variables from final models, or the suppression of insignificant coefficients even if the model was estimated with them, which can lead to selective representation of larger effect sizes (Aston et al. 2020b). If insignificant coefficients are suppressed for readability, but not removed from the model, the full model specification should be included in an appendix.

Conclusion and a research agenda

This article presents the state of the literature on the relationship between attitudes and transport choices. We summarize main findings regarding the overall importance of attitudes to predict transport-related choices, which attitudes are commonly included in models of transport choices, and how these relationships vary across the globe. We identify major challenges that prevent us from drawing further conclusions, and provide suggestions to address these in future research. In particular, STAMP (Appendix A) provides a comprehensive protocol for developing survey instruments that will reduce heterogeneity in attitudinal measurement. We now conclude with a research agenda to address understudied areas in this literature.

Longitudinal studies

Most of the studies in this literature use cross-sectional samples, which cannot easily shed light on the direction of causality between attitudes and behavior or the reliability of attitudes over time.

The lack of understanding of the direction of causality between attitudes and behavior frustrates deriving policy implications from this literature. While some research exists on this topic, more longitudinal research is needed to identify whether and how attitudes cause future behaviors. True longitudinal studies, where data is collected over a period of time, are the most useful (Panter and Ogilvie 2015; Böcker et al. 2016; Olde Kalter et al. 2020; van de Coevering et al. 2021). Quasi-longitudinal studies in which participants are asked to recall past actions can be prone to recall bias, especially over long time periods, but can nonetheless also provide insights into causal relationships between attitudes and behavior (Efthymiou and Antoniou 2017). Recall bias may be a particular concern with attitudes as they are subjective and intangible, unlike a previous neighborhood or income level.

There is relatively little research evaluating the stability of transport-related attitudes over time, and longitudinal studies will be able to contribute to this gap. The psychological literature suggests that attitudes are fairly stable, over both short (Jaccard et al. 1975; Haddock et al. 1993, p. 1108n3) and long (Craig et al. 2005; van de Coevering et al. 2021) time scales. Stability likely depends on the strength of the attitude (Krosnick 1988; Prislin 1996).

Relatively few researchers have investigated the stability of transport-related attitudes specifically. Some researchers have found stability to be moderate to low (Thøgersen 2006; Adams et al. 2013). However, more recent work suggests that transport-related attitudes are quite stable, similar to other types of attitudes, even over time periods of several months (Mirtich et al. 2021). Given that attitudes are generally correlated

with transport choices, and transport choices are stable, stability of attitudes would be expected as well. Longitudinal studies over longer time frames are needed to fully understand the evolution of attitudes.

There are two potential causes of attitudinal instability. One is that attitudes truly do change over time. The other is that there may be random measurement error in attitudes; if this error is sufficiently large, it may produce unstable measurements even in the presence of underlying, stable attitudes. The fact that attitudes appear to be relatively stable suggests neither of these are likely to be the case—underlying attitudes are stable over the short-to-medium term, and random errors in measurement are not sufficient to mask underlying attitudes.

Experimental studies

Policy interventions to affect attitudes and therefore behavior are potentially promising. However, it is not clear how difficult it is to influence attitudes through policy. We urge researchers to undertake studies that attempt to change people's transport-related attitudes, for instance through providing additional information about transport options and issues, and measure transportation outcomes. This requires careful consideration for the ethical issues implied. These study designs can also contribute to understanding the causal relationship between attitudes and behavior, and should be conducted as randomized control trials.

Forecasting of attitudes

To support long-range planning, travel model input variables must be forecast into the future (Ortúzar and Willumsen 2011, ch. 15). While methods for forecasting land use and demographic inputs are well-developed, it is unclear how to forecast future attitudes. Methods developed by psychologists to model the evolution of attitudes have generally been applied to short-term forecasting of specific attitudes, using high-fidelity data on social relationships—not something typically available to transport planners (e.g., Friedkin and Johnsen 1999). We encourage the study of methods for forecasting attitudes into the future.

Research in the global South

The global South is extremely understudied in the travel behavior literature, with research from South America or Africa appearing in only 4 of 158 reviewed articles. However, much could be gained from reducing this geographic bias. Africa is the most quickly urbanizing continent (Elmqvist et al. 2013) and South America, while highly urbanized, remains relatively nonmotorized (Hidalgo and Huizenga 2013); these contexts offer the opportunity to understand how the urbanization and motorization processes shape travel behavior. Additionally, modes such as informal transit and motorcycles which are not widespread in Europe or North America can be studied in the South American and African contexts, where they are much more prominent (Adoga 2012; Finn 2012; Hagen et al. 2016).

Appendix A: Standardised transport attitude measurement protocol (STAMP)

Matthew Wigginton Bhagat-Conway, Laura Mirtich, and Deborah Salon

The Standardised Transport Attitude Measurement Protocol (STAMP) is a list of attitudinal statements that we believe best represent key concepts associated with transport choices. Our explicit goal in creating STAMP is to improve the comparability of the results of future transport choice studies that incorporate subjective variables. In order to focus on key concepts, questions in STAMP have been chosen to reflect the most common attitudes studied in the literature. Researchers who are studying particularly specialized topics may find it useful to also consult this project's associated database for more specific questions.

There are 100 attitudinal statements in this section. We do not expect most surveys to include all of these questions, but we hope researchers will choose questions from STAMP related to the goals of their surveys. For instance, a planning organization wanting to improve its mode choice model might include questions from the comfort and convenience themes, while an organization looking to build a residential location choice model might include attitudinal statements about residential location choice and mode liking.

To create STAMP, we began with a list of approximately 2000 unique attitudinal statements that appeared in the reviewed literature. We organized these statements into categories as a team. An initial set of categories was created by one author. We then met and performed the bulk of the categorization in-person and in real time, creating new categories and splitting or combining categories as needed. Some additional papers were brought to the authors attention after this exercise had taken place. These were categorized by individual authors, but they largely duplicated the essence of existing questions so categorizations were uncontroversial. A small number of attitudinal statements didn't fit clearly into a category during the real-time categorization process, and were categorized later. We then chose 13 attitude categories to include in STAMP, and selected specific statements for each; these categories appear as sections below.

A modified Delphi bias-reduction method (Dalkey and Helmer 1963) was used to select statements in each category. First, three authors independently identified questions in the reviewed literature for potential inclusion in STAMP, then collated and shared the results. We then each independently chose approximately 5 questions in each category. These steps closely followed the Delphi method; while we knew the identity and choices of the other raters, we did not review the results of others until we had made our own choices. We discussed the results face-to-face to decide on the final instrument. During this conversation, we identified several gaps, which the first three authors filled by consensus.

It is not expected that the questions in STAMP will always load onto factors that match the 13 sections below; for instance, questions about driving safety and comfort may load onto a common driving factor, rather than separate safety and comfort factors.

Many of these statements are copied directly from previous survey instruments in this literature. Others reflect minor edits to regularize the format of all questions in the unified instrument, or represent combinations of multiple questions. Some researchers may prefer to make minor edits so that their survey will best suit the study context (for example, replacing "bicycling" with "cycling"). We expect that these questions will be presented to respondents with Likert-scaled response options from "Strongly Disagree" to "Strongly Agree"; a 5-point Likert scale is common in this literature.

Mode liking

Mode-liking refers to how people feel about a particular mode, or attributes of that mode. They are very common in mode-choice models, and tend to be strong predictors, but there can be endogeneity concerns with some of these questions.

Question	Source
Driving allows me freedom	Kitamura et al. (1997)
I'd rather have someone else do the driving	Mokhtarian et al. (2001)
I like [driving, bicycling, walking, taking public transport][a]	Aditjandra et al. (2013), Ye and Titheridge (2017), Zhou and Wang (2019), modified from Ettema and Nieuwenhuis (2017)

[a]This question is a very strong predictor of modal usage but is likely endogenous. We only recommend including this question in models of transport outcomes other than mode choice

Convenience

Convenience is often a powerful motivator for transport mode choice. Even when it is possible to measure aspects of convenience directly, for instance by measuring travel time, it may be valuable to measure perceived convenience as well. The attributes that make a mode convenient are often specific to a particular mode, so both general and mode-specific questions are included in this section.

Question	Source
I feel that I am wasting time when I have to wait	Kitamura et al. (1997)
If it would save time, I would change my form of transport	Popuri et al. (2011)
Predictable travel time is more important than a faster trip	Popuri et al. (2011)
I like to be able to run errands on the way to my destinations	Modified from Ramezani et al. (2018), Malokin et al. (2019)
I like to be able to carry things with me during day-to-day travel	Modified from Malokin et al. (2019)
Being productive during day-to-day travel is important to me	Similar question appears in Popuri et al. (2011)
Flexibility of departure time is an important factor in my day-to-day travel decisions	Modified from Akar and Clifton (2009)
I often need to change my daily travel plans at a moment's notice	Popuri et al. (2011)
The car offers me the flexibility I need for my schedule	de Abreu e Silva (2014)
I can count on the car to get me to my destination on time	de Abreu e Silva (2014)
Getting stuck in traffic doesn't bother me too much	Choo and Mokhtarian (2004), Kitamura et al. (1997); Mokhtarian et al. (2001), Schwanen and Mokhtarian (2005a, 2005b, 2007)
It is inconvenient to commute without a car	Zhou and Wang (2019)
Driving allows me to get more done	Kitamura et al. (1997)

Question	Source
It's hard to take public transport with bags or luggage	Modified from Atasoy et al. (2013), Bouscasse et al. (2018)
I like that I can get other things done while using public transport	Modified from de Abreu e Silva (2014)
I can count on public transport to get me to my destination on time	Modified from de Abreu e Silva (2014)
Planning a trip with public transport is complicated	Molin et al. (2016)
Using public transport takes too much time	Kamruzzaman et al. (2015a, b), Kamruzzaman et al. (2013, 2016), Kamruzzaman et al. (2015a, b)
Public transport is conveniently located to most of my destinations	de Abreu e Silva (2014)
It's hard to take public transport with young children[a]	Modified from Atasoy et al. (2013), Bouscasse et al. (2018)
It's hard to ride a bike with bags or luggage	Modified from similar question about public transport in Atasoy et al. (2013), Bouscasse et al. (2018)
There are no convenient routes for bicycling to the places I go	Modified from Adams et al. (2013)
It is difficult to keep up my personal appearance if I bicycle	Modified from Curto et al. (2016)
Many of the places I go are within bicycling distance of my home	Modified from Shirgaokar and Nural Habib (2018)
Bicycling is fast for local trips[b]	Developed by authors
It's hard to ride a bicycle when traveling with young children	Modified from a similar question about public transport in Atasoy et al. (2013), Bouscasse et al. (2018)
Many of the places I go are within walking distance of my home	Modified from a similar question about bicycling in Dill et al. (2014), Shirgaokar and Nural Habib (2018)
There are no convenient routes for walking in my neighborhood	Modified from Adams et al. (2013)

[a] We modified the question to not refer to the respondent's own children (since not all respondents will have children), and to be specific to young children since the difficulty of taking children on public transport varies with age

[b] This question was not asked specifically in any of the reviewed studies, but travel time is an important attribute asked of other modes so we included it here

Safety

Safety is an important part of the mode choice process for some individuals. This seems particularly true with active travel modes, which have significant safety concerns in the US (Pucher and Dijkstra 2003; Schmitt 2020). Safety concerns can be divided into three broad categories: personal safety, traffic safety, and property safety. Personal safety refers to freedom from threats of crime, muggings, harassment, etc. Traffic safety refers to freedom from threats of bodily harm due to traffic crashes. Property safety refers to freedom from threats of theft of a vehicle—mostly a concern for bicyclists, as bicycle theft is relatively common (van Lierop et al. 2015). Questions included in this section aim to capture both a respondent's general concerns about safety as well as their perceptions of the safety of different modes.

Question	Source
I often think about safety from crime when choosing how I get around	Developed by authors, similar question asked in Kuppam et al. (1999)
I often think about traffic safety when choosing how I get around	Developed by authors, similar question asked in Namgung and Akar (2015)
I'm not comfortable sharing a vehicle with strangers	Similar question asked in Atasoy et al. (2013), Bouscasse et al. (2018)
I feel safe taking public transport[a]	Similar concept found in Van Acker et al. (2014)
I feel safe at train stations and bus stops	Modified from Ingvardson and Nielsen (2019)
I don't feel safe getting to the bus stop or train station	Many authors ask about public transport safety (e.g., Van Acker et al. 2014); this separates safety accessing the service from safety on the service
When I drive, I worry about getting into a crash[b]	Modified from Popuri et al. (2011)
I need a car to protect me from threats to my personal safety	Developed by authors, similar question asked in Kuppam et al. (1999)
I don't feel safe driving at night	Developed by authors
Bicycling to places I generally go feels unsafe because of traffic	Many authors asked about bicycling safety (e.g., Gabrhel 2019), but there can be both personal and traffic safety concerns; this question clarifies
I am or would be concerned about theft when locking up a bicycle in the places I usually go	Developed by authors, similar question asked in Park and Akar (2019)
I worry or would worry about road safety when bicycling at night	Developed by authors
I don't feel confident bicycling in bad weather	Similar question asked in Curto et al. (2016)
At night I feel safe walking by myself in my neighbourhood	Noland and Dipetrillo (2015)
Traffic makes it unsafe for me to walk in my neighbourhood	Noland and Dipetrillo (2015)
I feel unsafe crossing major roads in my city on foot	Similar questions asked in Adams et al. (2013), Lee (2013)

[a]Since traffic safety on public transport tends to be high, we believe this primarily captures personal safety concerns

[b]Modified to replace the word "accident" with "crash" to be consistent with current best practices (Stewart and Lord 2002)

Comfort

Comfort is another common theme among the studies we reviewed. As with convenience and safety, comfort-related attitudes can vary significantly by mode, so we include in this section both general attitudinal statements and statements specific to particular modes. Overall comfort tends to depend on two distinct perceptions. One is physical comfort, as captured by questions such as "Protection from weather is important to me when choosing how I get around." However, a mode's perceived comfort is also dependent on one's feeling of stress or emotional discomfort while using that mode. Questions about privacy, stress, and identity tend to capture this component of overall comfort.

Question	Source
Privacy is important to me when choosing how I get around	Modified from Popuri et al. (2011)
Protection from weather is important to me when choosing how I get around	Similar question asked in Kuppam et al. (1999), Ramos et al. (2020)
Public transport is comfortable	de Abreu e Silva (2014)
Public transport is too crowded in my region	Similar question asked in de Abreu e Silva (2014)
The car is comfortable	de Abreu e Silva (2014)
Driving is stressful	Modified from Habib and Zaman (2012)
I consider myself a cyclist	Modified from Lois et al. (2015)
Biking is stressful	Maldonado-Hinarejos et al. (2014)

We did not identify any comfort-related questions about walking that are not adequately covered by the general comfort questions, and we believe walking to be more motivated by convenience and safety.

Environmentalism

Attitudes about the environment have been shown to impact transport outcomes, particularly in the choice to use public transport or active travel rather than driving (Kitamura et al. 1997). The questions below aim to capture awareness of environmental problems and a feeling of personal responsibility to alleviate them.

Question	Source
I am concerned about climate change	Modified from Atasoy et al. 2013
Jobs are more important than the environment	Modified from Kitamura et al. (1997)
From an environmental point of view, it is important we reduce car use	Xia et al. (2017)
We should increase the price of gasoline to reduce air pollution	Modified from Atasoy et al. (2013); Bouscasse et al. (2018)
Any changes I make to help the environment need to fit in with my lifestyle	Chng et al. (2019)
I am committed to an environmentally friendly lifestyle	Conway et al. (2020)
I am committed to using a less polluting means of transportation (e.g., walking, biking, and public transport) as much as possible	Modified from Circella et al. (2017)
Sometimes I worry about the effects of airplane trips on the environment	Developed by authors

Travel liking

People do not always perceive travel time to be a disutility (Redmond and Mokhtarian 2001), and attitudes can be a significant predictor of whether they do or not (Ory and Mokhtarian 2005). Questions in this section aim to understand how much people intrinsically enjoy travel.

Question	Source
Travel time is generally wasted time	Mokhtarian et al. (2001)
Commuting can be a useful transition between home and work	Modified from Choo and Mokhtarian (2004); Mokhtarian et al. (2001), Schwanen and Mokhtarian (2005a, b, 2007)
The only good thing about day-to-day travel is arriving at your destination	Mokhtarian et al. (2001), Schwanen and Mokhtarian (2005a)

Preference for urban built environment

The built environment around one's home can impact transport choices, but the opposite is true as well. For example, people who prefer to get around by bike may choose to live in areas where this is possible. Measuring attitudes towards residential location choice is thus important both to support models of residential location choice as well as to control for self-selection in transport choice models (Cao et al. 2009a, 2009b). The questions presented in this section aim to reflect preference for urban or suburban environments.

Question	Source
Having shops and services within walking distance of my home is important to me	Choo and Mokhtarian (2004), Mokhtarian et al. (2001), Schwanen and Mokhtarian (2005a, 2005b, 2007)
It is important to me to have easy access to nightlife	Developed by authors; many authors ask about restaurants and other destinations more broadly (e.g., Circella et al. 2017)
It is important to me to have space between me and my neighbors[a]	Modified from Kitamura et al. (1997)
It is important to me have a yard at my home[b]	Modified from Choo and Mokhtarian (2004), Mokhtarian et al. (2001), Schwanen and Mokhtarian (2005a, 2005b, 2007)
It is important to me to have a large home	Developed by authors; Scheiner and Holz-Rau (2007) asked about the role of home size and layout in the residential location choice process
It is important to me to live somewhere with easy access to public transport service	Modified from Ramezani et al. (2018)
It is important to me to live in a neighborhood with dedicated walking and bicycling paths[c]	Similar questions appear in Acheampong and Siiba (2018), Etminani-Ghasrodashti et al. (2018b, a); Zhao et al. (2018)
Having a short commute is important to me[d]	Developed by authors, similar question appears in Kamruzzaman et al. (2015a, b)
Living in a quiet neighborhood is important to me	Developed by authors, similar question appears in Handy et al. (2005)
Living in a safe neighborhood for children is important to me	Developed by authors, similar question appears in Handy et al. (2005)
It is important to me to live close to high quality schools	Modified from Guan and Wang (2019)

[a] "Prefer" is used to better align with the preference-based wording in other residential location choice questions

[b] The adjective "large" is removed to make the question more general

c Walking and cycling paths may not suggest an urban area but may suggest the availability of alternative transportation

d Constructed to capture this preference generally without specifically referring to a workplace that is not applicable for all respondents

Car pride

These questions aim to capture a feeling of prestige associated with car ownership and use. Some authors have found that car pride attitudes can predict both driving and vehicle type choice (Schwanen and Mokhtarian 2005b; Moody and Zhao 2019).

Question	Source
I take pride in owning a car	Daisy and Habib (2015)
To me, a car is a symbol of identity	Zhou and Wang (2019)
To me, the car is a status symbol	Choo and Mokhtarian (2004), Mokhtarian et al. (2001)

Car dependence

Some surveys find that respondents who don't perceive any other mode as a suitable alternative to the car drive more (Handy et al. 2005).

Question	Source
The car is nothing more than a convenient way to get around for me	Guan and Wang (2019)
We could manage pretty well with one fewer car than we have (or no car)	Handy et al. (2005)
I need a car to do some of the things I need or want to do	Modified from Kamruzzaman et al. (2015a, b), Guan and Wang (2019)

Lifestyle

These questions cover lifestyle attributes that are less directly related to travel but can be predictors of transport outcomes nonetheless (Van Acker et al. 2011). The questions in this particular category are unlikely to all end up loading heavily on a single latent variable.

Question	Source
I like to stay close to home	Modified from Choo and Mokhtarian (2004), Mokhtarian et al. (2001), Schwanen and Mokhtarian (2005a, b)
I like to be among the first to have the latest technology	Modified from Circella et al. (2017)
I like seeing people and having other people around me	Bouscasse et al. (2018)

Question	Source
I like to get exercise during my day-to-day travel	Developed by authors; many authors ask questions such as "bicycling is a form of exercise" (Bigazzi and Gehrke 2018); we recast this sentiment as a personal belief rather than a perception of a factual statement
I am too busy to do many things I'd like to do	Circella et al. (2017)

Social norm

Social norm is a part of the Theory of Planned Behaviour that reflects the attitudes and preferences of other important individuals to the respondent. For instance, people whose friends and family support them using public transport may be more likely to use public transport than those whose friends and family expect them to drive.

Question	Source
My family and friends typically [drive, bicycle, walk, use public transport]	Modified from Popuri et al. (2011)
My family and friends support or would support me [driving, bicycling, walking, using public transport]	Modified from Barberan et al. (2017)
People who are important to me own an electric car	Haustein and Jensen (2018)
People who are important to me think my next car should be electric	Modified from Haustein and Jensen (2018)

Working from home

Working from home has been a topic of interest to transportation researchers for many years (e.g., Mokhtarian and Salomon 1997), but the current COVID-19 pandemic has led to drastic increases in working from home, at least some of which are expected to persist beyond the pandemic (Conway et al. 2020).

Question	Source
Video calling is a good alternative to in-person business meetings	Conway et al. (2020)
It is hard to get motivated to work away from the main office	Modified from Mokhtarian and Salomon (1997)
I like working from home[a]	Conway et al. (2020)
I enjoy the social interaction found at a conventional workplace	Modified from Mokhtarian and Salomon (1997)

[a] There may be some endogeneity present here, as with the similar questions in the mode liking section, wherein people who do work from home come to enjoy (or despise) it

Cost

The cost of travel affects different people differently; some people may be price sensitive, while others do not think as much about price when making travel decisions. While these differences are likely correlated with income, they are probably not entirely explained by income. This is why we include attitudes toward transport costs in STAMP.

Question	Source
The price of gasoline affects the choices I make about my daily travel	Handy et al. (2005)
Regardless of cost, I choose the fastest way to get to my destination	Modified from Popuri et al. (2011)
Driving a car is expensive	Kamruzzaman (2013)
I would take public transport more if it were cheaper	Developed by authors; similar construct presented in Van Acker et al. (2014)

Appendix B: Search terms

The research included in this review was identified by searching the Scopus research database for keywords related to attitudes, analysis methods, and transport choices. These searches were conducted between Summer 2018 and Fall 2020. The table below outlines all of the search terms in each of these categories.

Attitudes	Analysis methods	Transport choices
Attitudes	Factor analysis	Mode AND choice
Beliefs	Principal components analysis	Transit
Perceptions	Principal component analysis	Public transport
	Structural equation model	Public transportation
	Structural equations model	Bus
	Integrated choice and latent variable	Rail
	Integrated choice latent variable	Bicycling
	Hybrid choice	Biking
	Latent class model	Bicycle
	Latent class choice model	Bike
		Pedestrian
		Car use
		Vehicle use
		Vehicle miles traveled
		Vehicle kilometers traveled
		Vehicle kilometres traveled
		VMT
		VKT
		Residential AND self-selection
		Car AND purchase
		Vehicle AND purchase

Attitudes	Analysis methods	Transport choices
		Car AND type
		Vehicle AND type
		Car AND ownership
		Vehicle AND ownership
		Residential AND location

The exact search syntax used was the following, which returned a total of 1,092 documents. After screening the results for our review inclusion criteria, we identified 158 studies to include in the systematic review.

```
PUBYEAR<2020 AND (
TITLE-ABS-KEY (attitudes OR beliefs OR perceptions).
AND
TITLE-ABS-KEY ((mode AND choice) OR transit OR "public
transport" OR "public transportation" OR bus OR rail OR bicy-
cling OR biking OR bicycle OR bike OR pedestrian OR "car use"
OR "vehicle use" OR "vehicle miles traveled" OR "vehicle kil-
ometers traveled" OR "vehicle kilometres traveled" OR "VMT"
OR "VKT" OR (residential AND self-selection) OR (car AND pur-
chase) OR (vehicle AND purchase) OR (residential AND loca-
tion) OR (vehicle AND type) OR (car AND type) OR (vehicle AND
ownership) OR (car AND ownership)).
AND
("factor analysis" OR "principal components analysis" OR
"principal component analysis" OR "structural equation model"
OR "structural equations model" OR "integrated choice and
latent variable" OR "integrated choice latent variable" OR
"hybrid choice" OR "latent class model" OR "latent class
choice model").
)
```

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Availability of data and material Database developed for this project is publicly available at https://files.indicatrix.org/attitudes.

Code availability Not applicable.

Declarations

Competing interests The authors have no competing interests to declare.

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