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Prospective avenues in travel behavior research supported by the cognitive dissonance theory: A scoping review

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ABSTRACT

Recent findings on the relationship between travel choices and attitudes toward different modes of transport have highlighted the importance of Festinger's Cognitive Dissonance Theory (CDT). Evidence suggests a bidirectional influence between travel behavior and attitudes, making CDT especially relevant. However, little attention has been paid to exploring CDT itself in the transportation domain. We present a scoping review that discusses the concepts defined by the seminal work of Festinger (1957) on CDT and recent considerations from psychology. We also discuss the gaps found in the transportation literature and suggest avenues for future research to enhance CDT's applicability. A conceptual model is presented to provide a rationale of the theory and four main questions are considered to drive the discussions throughout the paper: (i) How have cognitive dissonance definitions been interpreted and applied in the literature?; (ii) How has the magnitude of inconsistency been measured?; (iii) To which constructs has the cognitive dissonance state been related?; (iv) To what extent have resistances to behavior and attitude changes been considered? Addressing these questions contributed to present clearer definitions about the constructs of CDT, particularly to the term 'dissonance', the magnitude of inconsistency function and both resistance to behavioral change and resistance to attitude change. As a result, this paper provides a logical decision-making process regarding travel mode choice, allowing a balance between the assessment of soft and hard policy interventions toward sustainable mobility.

1. Introduction

Significant efforts have been made in the literature to predict travel behavior, especially mode choice (Ben-Akiva et al., 2002; Chorus et al., 2008; Gärling and Axhausen, 2003; Lois et al., 2015). Initially, studies only considered a limited number of factors correlated with mode choice, such as travel time, cost, and socioeconomic characteristics (De Vos et al., 2021; Ortúzar & Willumsen, 2011). Over time, other variables related to habits, the built environment, subjective well-being, and social networks have been taken

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into account to increase the predictive power of models (Gärling and Axhausen, 2003; van Acker et al., 2010; Kim et al., 2017; Chatterjee et al., 2020).

Similarly, attitudes defined as an individuals' positive or negative evaluation of an object or behavior (Ajzen, 1985) have become a prominent subjective variable in travel behavior research. According to De Vos and Singleton (2020), despite initial evidence suggesting a mutual dependency between attitudes toward a transport mode and behavior (e.g., mode choice), several researchers assume the unidirectional influence of attitudes on behavior, largely due to the prevalence of the Theory of Planned Behavior (Ajzen, 1985) and Hybrid Choice Models (Ben-Akiva et al., 2002). However, recent findings now suggest a return to the rationale of earlier studies due to strong evidence of a bidirectional relationship between attitudes and behavior (Kroesen et al., 2017; van Wee et al., 2019). Kroesen et al. (2017) showed that not only behavior influences attitudes, but also that such a relation is stronger than the opposite effect of attitudes on behavior.

The possibility of a bidirectional relationship between attitudes and behavior is a key concept within the constructs of the Cognitive Dissonance Theory (CDT) (Festinger, 1957). According to this theory, individuals always strive for consistency within themselves. In most situations, people seek to act in accordance with their beliefs, opinions, or attitudes. Therefore, CDT presents a framework to explain what people would do to minimize the effects of inconsistencies. Briefly, if an individual finds himself or herself in a situation of cognitive inconsistency between attitudes and behavior, it may trigger feelings of psychological discomfort, which in turn, motivates the individual to change either its behavior or attitudes to achieve consistency. However, the ease with which an individual changes one of these components relies on the degree of resistance to change its behavior or attitudes.

Based on the recent findings elucidated by the CDT, several authors have proposed new conceptual models to explain the complex and dynamic relationship between travel behavior and attitudes. De Vos (2022) introduced the built environment as a moderating factor in which travel-related attitudes and travel mode choice have both direct and indirect influence on each other. Aiming to explore the role of individuals' attitudes in both residential choice and travel behavior, Rahman & Sciara (2022) proposed a framework based on residential location preference, built environment, travel behavior, and travel-related attitudes, identifying several relationships among them, including a bidirectional relationship between travel-related attitudes and behavior. De Vos et al. (2021) proposed the so-called "travel mode choice cycle" framework, which connects travel behavior, satisfaction, attitudes, desire, and intention. Arroyo et al. (2020) analyzed the influence of personal values and companions, while mechanisms of attitudinal changes were discussed by van Wee et al. (2019).

While the concepts of the CDT have supported a wide range of applied research and case studies, such as residential location choices (Kamruzzaman et al., 2021; Mao et al., 2022), dissonance between actual and preferred commuting times (Ma, Van Acker, Lord, & Gerber, 2021; Ye, De Vos, & Ma, 2020), attentional dissonance (Imants et al., 2021), cycling dissonance (Zhang et al., 2022), traffic safety (Kwon et al., 2022), and dissonance between driving behavior and traffic laws (Gauld et al., 2021), this paper specifically focuses on cognitive dissonance associated with travel mode choice due to its implications on transport policy strategies. In several other studies, even when authors have not adopted CDT as the theoretical basis for their analyses, they noted that the outcomes of their research could be better analyzed using the CDT and provide empirical evidence of its relevance to travel behavior research (Gerber et al., 2020; Ito & Kawazoe, 2022; Piras et al., 2021).

While this evidence offers important insights into travel behavior research and policy implications for adopting sustainable travel modes, we advocate for revisiting the foundations of CDT to achieve a more comprehensive understanding of its framework and to demonstrate its applicability to the transportation field. Although CDT provides a relatively straightforward rationale and considerable flexibility in addressing several aspects that influence behavior and attitude changes in the transportation domain, we have identified some shortcomings that could be addressed to further promote the development of this theory in transportation research.

Initially, several misconceptions were identified concerning the interpretation, conceptualization, and application of the CDT constructs. The term 'dissonance' needs to be discussed to avoid ambiguity and conflicting results related to policy implications. Furthermore, the absence of standardized measures for attitudes makes it difficult to compare results across different contexts, leading to the identification of rudimentary measures of the conflict between attitudes and behavior. Additionally, some CDT constructs — such as resistance to behavioral and attitudinal change, along with key correlations between attitude-behavior conflict and the resulting psychological discomfort — remain largely overlooked in the literature.

Given the shortcomings identified in the literature regarding the early applications of the CDT in transportation engineering, this paper aims to provide a scoping review focused specifically on travel mode choice. First, we revisit the seminal work of Festinger (1957) to clarify the framework of CDT and reestablish definitions of important but overlooked constructs within the theory. Second, we discuss the gaps in literature and propose avenues for future research related to travel behavior mode choice from the perspective of the CDT constructs. Finally, we present a brief discussion of the policy implications derived from the findings of this scoping review, emphasizing the importance of this framework.

While a systematic review aims to address a clearly defined question, a scoping review encompasses broader topics where studies may employ varied methods and applications (Arksey & O'Malley, 2005). According to Munn et al. (2018), conducting a scoping review involves several important aspects: (i) identifying the types of existing evidence; (ii) clarify definitions and concepts; (iii) examine methods applied in a specific field; (iv) charactere concepts; (v) serve as a precursor to a systematic review; and (vi) identify and discuss gaps in the literature. This paper aligns with four of these characteristics (ii, iv, v, and vi) following the best reporting practices outlined by PRISMA-ScR (Tricco et al., 2018).

This scoping review distinguishes itself from previous review papers (De Vos & Singleton, 2020) by extending beyond the development of a consistent conceptual framework for travel mode choice. It revisits the foundations of CDT and analyzes how key definitions have been interpreted and applied in recent years, highlighting constructs that have been explored to a limited extent but hold significant potential to explain complex interactions within mode choice. Additionally, we propose avenues for future research to

test the applicability of the CDT framework and its implications for policymaking.

While the first review paper on this subject addresses the introduction of residential dissonance and travel mode dissonance (De Vos & Singleton, 2020), this paper focuses specifically on the latter topic, as it represents a classic and important subject in transportation planning (Ortúzar & Willumsen, 2011). Additionally, it highlights important implications for policymaking derived from the bidirectional relationship between attitudes and behavior in travel mode choice discussed by Kroesen et al. (2017).

The remainder of this paper is organized as follows. Section 2 outlines the methods used in the literature search on travel mode choice in the context of the CDT. Section 3 revisits the seminal work of Festinger (1957) and builds on the discussions by Vaidis and Bran (2018, 2019) to offer a more comprehensive conceptual model of CDT, along with clearer definitions of its constructs. Results and discussions on the literature gaps and avenues for future research are presented in Section 4. Section 5 provides a brief discussion of policy implications, followed by conclusions and limitations of the scoping review presented in Section 6.

2. Methods

The first step of this scoping review explored the seminal work of Festinger (1957) to present its main concepts, definitions, and constructs of the CDT. While Vaidis and Bran (2018, 2019) have already clarified the originally ambiguous constructs of the theory, we build upon their discussion to provide insights into those definitions that still require further research in travel behavior.

In the following step, a literature search was conducted with the following keywords: ["travel" OR "transport*"] AND ["dissonance" OR "cognitive inconsistency" OR "cognitive mismatch" OR "incongruence"] in eight combinations. The search focused on the Web of Science platform due to the substantial coverage of journals and papers on the selected topics within the transportation field. This approach avoided excessive filtering of duplicate documents without the risk of overlooking important information. The search was limited to peer-reviewed journal articles written in English up to January 2024. Although snowballing techniques were not applied, we also analyzed the papers cited by De Vos and Singleton (2020) in the literature research.

While the research field has extensively explored several aspects of the CDT in travel behavior as discussed in Section 1 of this paper, our study focuses specifically on travel mode choice dissonance. This refers to the inconsistency between individuals' attitudes toward travel modes and their mode-choice behavior. This focus is evident in the screening criteria for our literature review, in which studies not directly related to this topic were excluded.

The analysis of Festinger's (1957) research guided our investigation on the following question: how have the constructs and definitions been interpreted and applied in the context of travel mode choice? Four key questions, discussed in the following sections of this paper, were established as criteria for selecting relevant studies. Drawing from evidence in other travel mode choice research, we provide insights into addressing these issues, highlighting the benefits of using CDT as a theoretical framework in this area. This leads to the identification of future research directions. Lastly, we consolidate the discussion on policy implications. The method of this scoping review is summarized in the flowchart of Fig. 1.

3. Revisiting Festinger's model

Festinger (1957) stated that people strive for internal consistency among their personal values, attitudes, beliefs, and actions while continuously facing a variety of choice tasks in everyday life. According to CDT, when dissonant attitudes are observed (e.g., a driver who demands more road safety but advocates high-speed vehicle traffic) or behavior is incongruent with attitudes (e.g., bike lovers

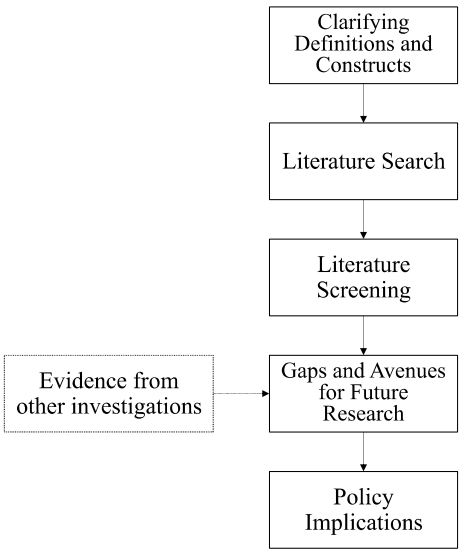

Fig. 1. Flowchart of the literature search method.

who drive to work), one may experience a negative affective state characterized by psychological discomfort, tension, or arousal. Such a psychological state motivates the individual to eliminate this discomfort — or reduce it to an acceptable level — in order to achieve internal consonance (Festinger, 1957; McGrath, 2017).

In transport-related decisions concerning travel mode choice involving user behavior, attitudes refer to the positive or negative evaluations about each transport mode. For instance, individuals who hold negative attitudes toward a particular mode but still choose it for their trips are clearly inconsistent when comparing their attitudes with their behavior (e.g., public transport users who find buses to be uncomfortable and unreliable). According to CDT, such inconsistency may lead to psychological discomfort, motivating individuals to either change their attitudes or behavior.

The CDT framework consists of a three-step process: (Step A) the existence of a cognitive inconsistency between attitudes and behavior can trigger the (Step B) generation of an aversive arousal or psychological discomfort, which, in turn, would lead to the (Step C) motivation for regulation strategies to reestablish consistency (Vaidis & Bran, 2018). However, Vaidis and Bran (2019) argued that Festinger (1957) used the term dissonance to refer to three different concepts: (i) the theory itself; (ii) the triggering situation (Step A); and (iii) the generated psychological state (Step B). According to those authors, this ambiguity became a barrier to further development of the theory because it overshadowed the importance of the sequence of the stages. Furthermore, while some researchers tried to eliminate dissonance by focusing on aversive arousal (e.g., devising methods to reduce aversion, i.e., increase satisfaction levels), others focused on the causes of inconsistency. However, both perspectives overlook the causal relationship between them, as discussed in this paper within the context of travel mode choice.

To avoid such confusion, Vaidis and Bran (2018) recommend referring to “inconsistency” to describe the relationship between cognitions and behavior, to the term “cognitive dissonance state (CDS)” to denote the psychological discomfort derived from this inconsistency, and to the term “Cognitive Dissonance Theory (CDT)” to refer to the theory itself.

Based on these definitions and assumptions, we proposed the conceptual model illustrated in Fig. 2. The three-step process is embedded in what we refer to as the “Dissonance Cycle,” where changes in both behavior and attitude continue to happen indefinitely until the psychological discomfort no longer exists.

According to Festinger (1957), for the theory to be empirically relevant it is necessary to unequivocally identify cognitive consistencies and inconsistencies (Step A). However, the author emphasizes that describing the relationship between attitudes and behavior is not only important from the qualitative perspective (i.e., define individuals as consistent or inconsistent), but also from the quantitative aspect (i.e., each individual presents different degrees of consistency and inconsistency). For instance, quantifying the degree of cognitive inconsistency is important in analyzing the potential effects of the interventions targeting changes in behavior and/or attitude because it defines the pressure to reduce or eliminate the CDS.

Festinger (1957) also defined the construct ‘magnitude of dissonance’ — herein referred to as ‘magnitude of inconsistency’ — as a function that compares the intensity of the behavior with the degree of attitude. The author states that the magnitude of inconsistency depends on the proportion of elements (or items composing the attitudinal measure) dissonant to behavior, in cases where elements have the same importance for the individuals. However, the magnitude of inconsistency could also depend on the weights assigned to

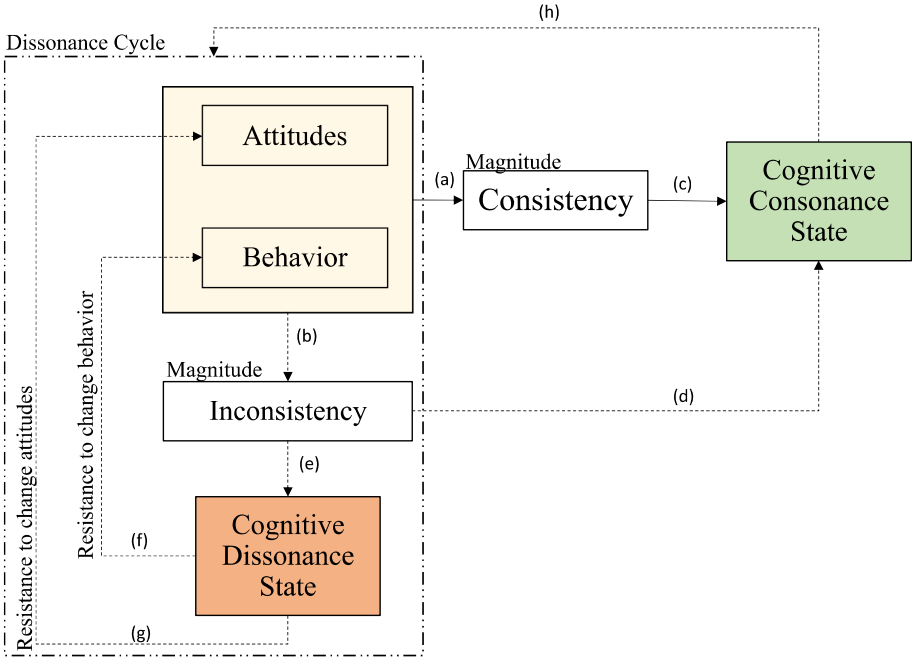

Fig. 2. Conceptual Model of the CDT.
Adapted from Festinger (1957).

these attitudinal items if they are assigned different weights depending on the context. In transportation contexts, such a perspective is intuitive because evaluating a mode depends on its degree of accessibility, affordability, sociodemographic factors, and personal values. For instance, assessing the relative importance of comfort or monetary cost will vary among individuals.

Unfortunately, Festinger (1957) did not provide sufficient details on how the magnitude of inconsistency function could be operationalized, but noted that a continuous measure is more informative than a categorical variable. However, regardless of how it is measured, a greater mismatch between attitudes and behavior will result in a larger magnitude of inconsistency, while a smaller mismatch between them will lead to a greater magnitude of consistency (arrows (b) and (a) in Fig. 2, respectively).

Therefore, the following situations may arise once the magnitude of cognitive (in)consistency is obtained: (i) if either a non-relevant relationship between attitudes and behavior or a magnitude of consistency exists, no psychological discomfort caused by such a relationship is expected, which implies the existence of a Cognitive Consonance State (CCS) (arrow path (c) in Fig. 2); (ii) the cognitive inconsistency may lead to CDS (arrow path (e) in Fig. 2) that motivates individuals to reduce or eliminate it.

However, not every choice is straightforward. According to Vaidis and Bran (2019), the relationship between cognitive inconsistency and CDS is more complex than a simple presence–absence relationship. It relies on the degree of inconsistency tolerance. Festinger (1957) emphasized that some residual cognitive inconsistency could remain after a choice has been made because individuals may negatively evaluate some aspects of the chosen alternative and evaluate the positive aspects of non-chosen alternatives simultaneously. In both cases, residual inconsistency remains. Therefore, it seems that the absence of the CDS will likely occur in the presence of low levels of cognitive inconsistency; that is, the individual is in a CCS (arrow path (d)). Therefore, low levels of inconsistency may not be perceived or relevant (Step A of the CDT framework), and consequently, will not trigger the CDS. This is important because the CDS motivates individuals to seek strategies for its elimination. Therefore, identifying the existence of CDS is essential to the theory (Step B of the CDT framework).

Vaidis and Bran (2019) noted that several questions concerning the exact meaning of psychological discomfort remain unanswered. They argue that different definitions of CDS are presented in the literature, for instance, as a state of tension, aversive arousal, or an unpleasant feeling. However, it is unclear whether CDS is a specific state or can be defined by emotions such as guilt, surprise, anger, disappointment, or frustration. The authors acknowledge this lack of information about CDS and suggest both an intensive and extensive examination of the topic.

The last step embedded in the Dissonance Cycle refers to the regulation strategies used to achieve CCS (Step C of the CDT framework). Festinger (1957) argued that inconsistency could be reduced in three ways: (i) individuals may change their behavior to align with attitudes; (ii) the environmental cognitive element is modified, i.e., the external factors or situations where inconsistencies occur are modified; or (iii) the cognitive elements that make up attitudes can be altered by eliminating, adding, or reevaluating the attitudinal items. McGrath (2017) provides a good overview of the reduction strategies.

However, both behavior and attitudes often remain unchanged, defining the resistance to change (Vaidis & Bran, 2018). The extent of this resistance relies on the nature of the influencing factors. According to Festinger (1957), changing behavior (arrow path (f)) can be painful or involve loss; the existing behavior might be satisfying, or change might not be possible due to physical, psychological, or external factors. Meanwhile, changing attitudes (arrow path (g)) may be linked to cognitive rigidity, personality, and the social environment.

In this context, Festinger (1957) outlined a logical mechanism within the Dissonance Cycle tied to the magnitude of inconsistency and resistance to change. The maximum inconsistency between behavior and attitude is equal to the total resistance to change of the leat resistant element. If the magnitude of the dissonance exceeds this threshold, the less resistant element will change, thereby

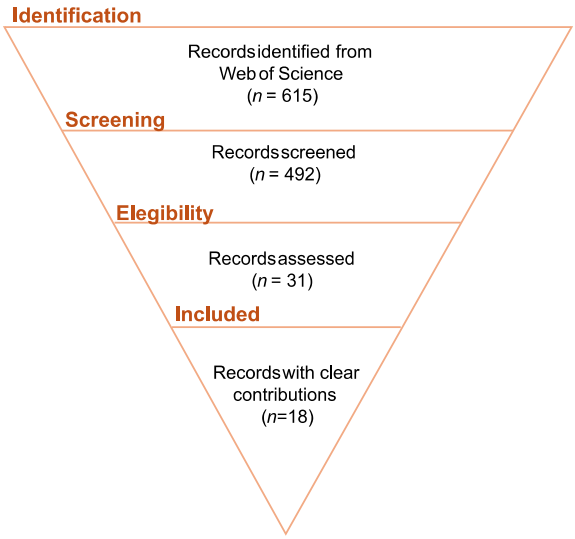

Fig. 3. Outcomes of the literature search process.

Table 1
Summarized search that support the findings discussed in this paper.

Reference	Definition of Travel Mode Dissonance	Measuring magnitude of inconsistency	Cognitive Dissonance State	Resistance to change behavior	Resistance to change attitude	Main Conclusions
Reibstein and Lovelock (1980)	Inconsistency between attitudes and behavior	Not measured	Not defined	Not mentioned	Not mentioned	There is a mutual influence between attitudes and behavior.
Tertoolen et al. (1998)	Discrepancy between attitudes and behavior	Not measured	Psychological tension	Self-monitored car use	Environmental, financial awareness	Given the existence of a cognitive inconsistency, people tend to change attitudes more easily than behavior.
Domarchi et al. (2008)	Gap between attitudes and behavior	Not measured	Uncomfortable feeling	Not mentioned	Not mentioned	Habitual car use can create or strengthen attitudes toward that mode due to the tendency to reduce cognitive dissonance.
Wang and Chen (2012)	Not directly defined	Not measured	Psychological tension	Not mentioned	Not mentioned	Individuals who switched from Single Occupancy Vehicle (SOV) to carpool adjusted their attitudes to match their behavior, while the SOV to carpool switchers adjust behavior to match attitudes.
Kaplan et al. (2014)	Feeling of stress and discomfort in the presence of contradictory attitudes and behavior	Not measured	Feelings of stress and discomfort	Not mentioned	Not mentioned	It is equally plausible that the price/mode is fair and spatially equitable in order to justify their choice, or that frequent users of transit convince themselves that the transit price/mode is fair and spatially equitable in order to justify their choice.
Kroesen et al. (2017)	Inconsistency between attitudes and behavior	Absolute difference between the 5-point behavioral scale and 5-point attitude scale	Psychological tension, state of stress/arousal	Not mentioned	Not mentioned	Attitudes and behaviors influence each other over time, but the effects from behavior to attitudes are greater than vice versa.
De Vos (2018)	Inconsistency between preferred and actual (travel) mode	Binary classification of individuals: consonants and dissonants	Feelings of discomfort, or dissatisfaction	Lack of travel-related skills, lack of travel options, presence of travel barriers, presence of travel habits	Not mentioned	Choosing the non-preferred travel mode (dissonance) affects travel satisfaction.The effect of travel satisfaction can also affect mode-related attitudes or the choice itself.
Stark et al. (2019)	Inconsistency between preferred and actual (travel) mode	Binary classication of children: consonants and dissonants	Lower levels of psychological well-being (PWB)	Freedom of choice	Not mentioned	Weak association of consonance vs. dissonance of mode use and PWB. But in case of consonance, children had a significantly higher well-being.
Ton et al. (2019)	Inconsistency between preferred and actual (travel) choice	Binary classification of individuals: consonants and dissonants	Not mentioned	Not mentioned	Not mentioned	Individuals are more positive toward the modes included in the daily mobility pattern, compared to the modes that are not part of it.
Zarabi et al. (2019)	Discrepancy between attitudes and mode choice	Binary classification of individuals: consonants and dissonants	Commute satisfaction, life satisfaction	Not directly mentioned	Sociodemographic, spationtemporal access, skills and competences	Consonant commuters can still be unsatisfied, while dissonant commuters can be satisfied. Consonance-dissatisfaction can be an outcome of a temporary inadequacy related to the mode used or due to dissatisfaction vis-à-vis

(*continued on next page*)

Table 1 (*continued*)

Reference	Definition of Travel Mode Dissonance	Measuring magnitude of inconsistency	Cognitive Dissonance State	Resistance to change behavior	Resistance to change attitude	Main Conclusions
						non-mode travel attributes.
Ye and Titheridge (2019)	Mismatch between attitudes and mode choice	Dummy variable indicating a mismatch	Travel satisfaction	Not mentioned	Not mentioned	A mismatch between travel attitudes and travel mode choices had a negative effect on commuting satisfaction.
Hoffmann et al. (2020)	Not defined	Not measured	Not mentioned	Not mentioned	Feelings of responsibility; new information; memorable experiences	Presentation of several strategies for mode-related attitude change.
Mella Lira and Paez (2021)	Affective dissonance: inconsistency between ideal and actual travel mode	Multiple dummy variables: direct comparison between travel mode use and each attitude-related item	Subjective well-being	Breaking the taboos related to subjective well-being and transport modes	Not clearly stated	Using different measures of inconsistency and analyzing how it is associated with sociodemographic characteristics increases the granularity of the analysis as well as the policy implications.
McCarthy et al. (2021)	Unpleasant psychological state caused by the mismatch between attitudes and the experience of cognitive dissonance	Binary classification of individuals: consonants and dissonants	Unpleasant feeling or tension	Not mentioned	Not mentioned	(i) Dissonant travelers are more likely to change. Infrequent users with positive attitudes are more likely to change, indicating that this is less cognitive distressing than frequent users with negative attitudes; (ii) Changing attitudes or behavior depends on the travel mode; (iii) life events are positively associated with dissonance.
An et al. (2022)	An unpleasant emotional state evoked by the incompatibility between relevant cognitions	Classes of incompatibility: attitudes versus the primary mode, the secondary mode, and the existing mode set	Unpleasant emotional state evoked	Not mentioned	Not mentioned	Dissonant individuals change either mode use or corresponding attitudes. Attitudes may have an impact on mode use decisions when multimodal travel behavior is involved, but such an impact may not necessarily be decisive.
Hu et al. (2023)	Inconsistency between preferred and actual (travel) mode	Binary classication of individuals: consonants and dissonants	Feelings of discomfort and dissatisfaction	Transport resistance factors (eg, distance, cost, and effort)	Not clearly stated	(i) Travel satisfaction is more influenced by the travel mode used by individuals rather than whether the chosen travel mode is preferred or not (dissonance); (ii) The occurrence of travel mode dissonance was unrelated to travel mode availability but instead to travel distances. To some extent, this explains the higher percentage of dissonant travelers that are men.
Kroesen et al. (2023)	Inconsistency between attitudes and behavior	Not directly measured	Not mentioned	Not mentioned	Not mentioned	People mutually adjust their attitudes and behaviors over time. This finding invalidates theories that assume that attitudes act as (stable) precedents of behavior and

(*continued on next page*)

Table 1 (*continued*)

Reference	Definition of Travel Mode Dissonance	Measuring magnitude of inconsistency	Cognitive Dissonance State	Resistance to change behavior	Resistance to change attitude	Main Conclusions
						favors theories that do account for reciprocal effects.
Pani et al. (2023)	Inconsistency between preferred and actual (travel) choice	Binary classification of individuals: consonants and dissonants	Feelings of discomfort and dissatisfaction	Lack of travel-related skills, lack of travel options, presence of travel barriers, and presence of travel habits	Not mentioned	(i) Mode-specific attitudes play a significant role in determining multimodal travel choices; (ii) significant bidirectional relationships exist between attitudes toward private and public transport mode choices; (iii) satisfaction levels are significantly higher for consonant travelers; (iv) significant gender disparities exist in travel satisfaction between men and women, particularly for dissonant travelers.

reducing the inconsistency.

Although individuals seek to remain in the CCS, external disturbances in resistance to change behavior and attitude may lead to a new dissonance cycle (arrow path (h)). This occurs when new information about existing attitudes or current behavior becomes available to individuals, leading to questioning the *status quo*. There are several sources of new information in transport behavior, such as relocating to a new city or neighborhood, the availability of new modes of transportation and technology, social influence, and new scientific evidence supporting a specific behavior.

4. Searching results and discussion

Fig. 3 presents the outcomes of the literature search carried out in this scoping review. The search using the eight combinations of the aforementioned keywords resulted in 615 papers. During the identification phase, duplicated papers as well as those outside of the scope of transportation research were removed from the database. Then, a screening process of the remaining 492 documents revealed a wide range of applications of CDT in travel behavior research. Much emphasis has been placed on residential dissonance, specifically the conflicts between preferred and actual land-use patterns in residential neighborhoods (Kamruzzaman et al., 2021). Applications were also found in the domains of traffic safety and laws, and attentional dissonance (Gauld et al., 2021; Imants et al., 2021; Kwon et al., 2022). Given our focus on travel mode choice, the latter documents were not considered.

An additional cutoff was established to narrow down the proposed search. While several papers could be classified within the travel mode choice domain, their approaches diverge somewhat from our goals. For instance, Humagain and Singleton (2020), Ma et al. (2021) and Ye, De Vos, and Ma (2020) adopted the CDT rationale to describe the impact of dissonance between actual and ideal commuting time on travel satisfaction. Zhang et al. (2022) defined cycling dissonance as the conflict between cycling potential and cycling itself when analyzing bicycle adoption. At the end of this step, the list was reduced to 31 studies.

Based on the proposed CDT framework described in Section 3, four key questions were identified and discussed in the following subsections as fundamental for assessing the contributions and gaps in developing CDT as a consistent theoretical framework for analyzing the travel mode choice process: (i) How have cognitive dissonance definitions been interpreted and applied in the literature? (ii) How has the magnitude of inconsistency been measured? (iii) To which constructs has the CDS been related? (iv) To what extent have resistances to behavioral and attitudinal changes been considered? These questions were used as eligibility criteria, ensuring they would provide valuable insights to our discussion.

Upon careful review of these studies, it was noted that some documents did not directly contribute to answering these questions due to several reasons. While the authors referenced some of their results in relation to CDT concepts, their methods and analyses were not grounded in its framework. This is the case of Acheampong et al. (2023), who analyzed the influence of perceived benefits of car-based ride-hailing, attitudes toward car use, social-symbolic values of car ownership, and attitude toward the environment on car ownership and use aspirations. The results showed that individuals with pro-environmental attitudes recognize the negative impacts of car use, but still maintain positive attitudes towards it. A similar approach is also observed by Abou-Zeid and Fujii (2016), Belgiawan et al. (2016), Chen and Lai (2011), Fu et al. (2018), Li (2018), Susilo and Cats (2014), Thigpen (2019), and De Vos et al. (2020).

Other papers specifically focus on the CDT. The main advantage of adopting the theory as a framework for modeling travel mode choice is its reliance on the bidirectional relationship between attitudes and behavior (travel mode choice). Kroesen and Chorus (2020) highlight this aspect, while van Wee et al. (2019) discuss the processes behind the attitude change due to the bidirectional relationship between attitudes and behavior. While they make significant contributions to adopting CDT definitions, the authors focused more on

developing their own frameworks than on advancing the development of CDT.

The paper by Horowitz (1978) was unavailable for review despite several requests and searches, hindering any discussion or conclusion. A final list of 18 documents with relevant contributions based on the four questions proposed in this paper is presented in Table 1. While the primary discussions are based on this list, papers from the initial list of 31 studies were occasionally cited.

4.1. Interpretation and application of definitions and constructs in the literature

As noted by Vaidis and Bran (2019) in the field of psychology, we argue that the term "dissonance" should also be defined in the transportation domain. While Wang and Chen (2012) avoided using the term itself, their findings align with most of the reviewed papers in Table 1. Most studies define "dissonance" as the mismatch between attitudes and behavior, often referred to interchangeably as inconsistency, incongruence, and discrepancy. This definition is equivalent to the description of Vaidis and Bran (2019) for cognitive inconsistency. Meanwhile, An et al. (2022), Kaplan et al. (2014), McCarthy et al. (2021), and Mella Lira and Paez (2021) adopted definitions closely related to the CDS as they relate dissonance to a psychological discomfort or an unpleasant psychological or emotional state.

The existence of such ambiguous and diverse definitions of dissonance can result in misleading policy implications because of the three-step process discussed in Section 3. For instance, An et al. (2022) found that multimodal travelers often choose modes of transportation they dislike, even though such inconsistencies do not necessarily lead to a CDS. This implies that a certain degree of cognitive inconsistency exists without causing psychological discomfort. Consequently, studies that define 'dissonance' simply as a mismatch between attitudes and behavior, ignoring whether it leads to a CDS or not, could suggest futile policy strategies centered on reducing inconsistency. Without knowing whether individuals exhibit a CDS, it is not possible to ensure that they are motivated to change either their attitudes or behavior.

On the other hand, studies assuming dissonance as a simple psychological discomfort, and ignoring the existence of cognitive inconsistency will likely face difficulties in suggesting policy interventions because it becomes hard to find an argument for deciding whether to invest resources in hard or soft interventions without evidence of the cause of such discomfort (Bamberg et al., 2011). Therefore, establishing a causal link between CDS and cognitive inconsistency is essential for the conceptual model proposed in this paper, which begins with a discussion of terminology. We strongly recommend that future research consider the definitions put forth by Vaidis and Bran (2018).

In the operationalization of the conceptual model, it was further noted that travel mode inconsistency is frequently defined as an inconsistency between the preferred mode and that actually chosen (De Vos, 2018; Hu et al., 2023; Ton et al., 2019; Zarabi et al., 2019). In this case, the preferred mode is the one with the most positive overall attitudes by the individual. While it is a useful strategy for measuring inconsistency, there are several reasons to consider it as relatively inadequate conceptualization. First, it has often been operationalized as a categorical measure ignoring the degree of intensity. In this context, there is no difference between an individual who dislikes public transport and uses it just once a week and a person who travels every day with it.

Second, assuming an aggregate measure for attitudes (e.g., summing the scores of attitude-related items) for choosing a preferred mode makes it more difficult to assess which attitude-related items are subject to intervention by decision-makers. Although Mella Lira and Paez (2021) defined dissonance as the mismatch between affective values, and the primary mode, they analyzed different 'cognitive inconsistencies', one for each affective value in comparison to the primary mode. Such a fine-grained assessment could be beneficial for assessing attitude-related items affected by policy interventions.

Adopting the preferred mode approach to measure cognitive inconsistency may create scenarios that are hard to explain. For example, when a public transport user is consistent (i.e., public transport is in fact the preferred mode, followed closely by car) yet still experiences a CDS. In this case, it is quite probable that the CDS is caused by the cognitive inconsistency related to not using the car, especially if his or her attitudes toward the car are similar to those toward public transport. Adopting the preferred mode approach as seen in the literature cannot explain such conflicting results.

Furthermore, researchers must also consider that individuals may tolerate low levels of cognitive inconsistency across several travel modes without experiencing a CDS. Thus, developing a mode-specific magnitude of inconsistency measure could help researchers to estimate such tolerance levels, when present, as well as establish how and which modes contribute to the existence of a CDS.

4.2. Measuring magnitude of inconsistency

The reviewed papers often relied on categorical measures of inconsistencies. Individuals are referred to as "consonant" or "dissonant" — i.e., consistent or inconsistent — travelers regarding the chosen travel mode (De Vos, 2018; Hu et al., 2023; McCarthy et al., 2021; Mella Lira & Paez, 2021; Pani et al., 2023; Stark et al., 2019; Ton et al., 2019; Ye & Titheridge, 2019; Zarabi et al., 2019). Although this approach results in important insights, it is a crude measure that makes it more difficult to gather deeper insights into the mechanisms outlined in the conceptual model of Fig. 2.

When attitudes and behaviors are not of equal magnitude (Festinger, 1957), a continuous measure of the degree of cognitive inconsistency is expected. To the best of our knowledge, the closest variable to this concept was proposed by Kroesen et al. (2017), in which the magnitude of inconsistency refers to the absolute difference between the intensity of behavior, calculated as the frequency of using a transport mode, and the intensity of attitude toward that mode. However, the proposed measure is an ordinal scale ranging from zero (for consistent travelers) to four (for inconsistent travelers). In this way, the magnitude of inconsistency of individuals has been estimated regardless of their nature, i.e., whether it exists because the person chooses a mode despite having negative attitudes, or because the person refrains from using a mode to which the person has positive attitudes. Such simplification makes it difficult to assess

whether to propose policies aiming to primarily change attitudes or behavior.

Proposing a new indicator for the magnitude of inconsistency represents a promising direction for future research. It should enable the measurement of both behavior and attitudes in a comparable manner. Measuring behavior is generally more intuitive due to its direct observability. The intensity of behavior is typically defined by the frequency of transport mode use (Haustein & Kroesen, 2022; Hu et al., 2023; Kroesen et al., 2023; McCarthy et al., 2021; Stark et al., 2019; Ton et al., 2019; Wang & Chen, 2012) or the distance traveled using each mode over a specific period (Kroesen et al., 2017; Kroesen & Chorus, 2020). These measures also indirectly consider the dynamic aspects of travel mode choice, which are different according to the circumstances (cost, weather, travel time, among others) and could influence the intensity of behavior regarding different transport modes.

Nonetheless, several challenges emerge when attempting to measure attitudes. According to Kroesen and Chorus (2020), who introduced the concept of a Psychological Network for evaluating latent variables, the prevailing approach posits that such variables are observed indirectly through a series of statements, also referred to as "items" assessed by the individuals. Examples of items are "Using the car is bad for the environment" or "Travel by bus is expensive". Identifying which items most effectively bring out the proposed latent variable depends on measurement frameworks such as Classical Test Theory and Item Response Theory (Crocker & Algina, 2008).

The primary issue in measuring attitudes within the transportation domain is the absence of a standard measure or scale, as noted by Bhagat-Conway et al. (2022). Upon reviewing 158 papers, the authors found 2,864 unique subjective survey questions that aimed at obtaining subjective or latent variables. In the papers evaluated in our study, we found 58 unique items to measure attitudes toward different travel modes. This diversity presents a challenge when comparing attitudes across different applications.

Items have been assessed using several methods such as the use of 5-point ordinal scales (Chen & Lai, 2011; Domarchi et al., 2008; Hu et al., 2023; Kroesen et al., 2017; Kroesen & Chorus, 2020; Ton et al., 2019; Ye & Titheridge, 2019), 7-point ordinal scales (Belgiawan et al., 2016; Wang & Chen, 2012) or dichotomous statements (De Vos, 2018; Stark et al., 2019; Zarabi et al., 2019). However, different methods may yield distinct results (Brown, 2015).

Another limitation is the operationalization of attitudinal variables. In De Vos (2018), the degree of attitudes toward travel mode was represented by the sum of 16 binary items ("Yes" — 1; "No" — 0). A usual and straightforward method is to assume, for instance, that responses collected through ordinal scales are interval data, i.e., that consecutive categories such as 1 — "Strongly Disagree" and 2 — "Disagree" are equally distant, which allows for the computation of the attitudinal variables as the total sum or average of the items (Hu et al., 2023; Kroesen et al., 2017; McCarthy et al., 2021). Other researchers applied Principal Component Analysis to extract an attitudinal factor and their respective scores (An et al., 2022; Haustein & Kroesen, 2022; Wang & Chen, 2012; Ye & Titheridge, 2019).

Although interval-based data allows the analysis of sums, means, and standard deviations — and consequently, the application of parametric tests — there is an ongoing controversy regarding its validity (Carifio & Perla, 2008; Kampen, 2019; Liddell & Kruschke, 2018; Pell, 2005; Rusch et al., 2017; Wu & Leung, 2017). For instance, Liddell and Kruschke (2018) demonstrated that treating ordinal scales as interval data may fail to detect non-zero effects (Type II errors) or effects that are not true (Type I errors), which can result in significant loss of explanatory power of the phenomenon and misinterpretation of the results. In addition, researchers should replace Pearson's correlation with polychoric correlation matrices when conducting Exploratory Factor Analysis to achieve more accurate results (Holgado–Tello et al., 2010).

In this context, the heterogeneity of the items and the diversity of methods for extracting attitudinal information, as well as for calculating attitudinal metrics, are significant barriers that hinder not only the application and testing of CDT within the transportation domain, but also any theories considering attitudes as constructs. The lack of a standardized measure complicates comparisons across different contexts and the interpretation of results, thus adding complexity to the process (Bhagat-Conway et al., 2022). However, when researchers aim to gather information about travel satisfaction and travel mood using the Satisfaction with Travel Scale and the Travel Mood Scale, respectively, these issues are mitigated by the standardized scales (Ettema et al., 2011; Friman et al., 2013; Glasgow et al., 2018).

Another relevant factor to consider when proposing an indicator of inconsistency is the potential weighting of cognitive elements and the relative importance of attitude-related items (Festinger, 1957). This aligns with Ajzen's (1985) assertation that the measurement of the attitude construct should be a product of expectancy and evaluation, i.e., the evaluation of the items is multiplied by their relative importance. An et al. (2022) and Domarchi et al. (2008) employed this approach. In the study by Zarabi et al. (2019), individuals assigned weights to their attitudes based on their personal values, thereby creating a weighted decision matrix.

Incorporating the relative importance of attitude-related items allows for the evaluation of different inconsistency reduction strategies such as trivialization (McGrath, 2017). In this case, we also suggest testing latent variable interaction methods (Miles et al., 2015; Schoemann & Jorgensen, 2021) to assess the moderation effects. It is important to determine if results are different among groups, for instance, the assessment of a mode-related attitude scale with regard to gender and income levels.

According to Vaidis and Bran (2019), measuring the magnitude of inconsistency has been underexamined in the literature, mainly because most studies actually report on the use of a dissonance reduction strategy. This rationale relies on the assumption that if individuals employ dissonance reduction strategies, inconsistencies and CDS must have been present to some extent. Otherwise, they would not adopt such strategies. However, it does not reveal anything about the nature of CDS or the magnitude of inconsistency.

Based on the above discussion, a few research directions could be explored. First, the need for an in-depth effort to propose a standard attitude scale similarly to the Satisfaction with Travel Scale, such as Ettema et al. (2011). Such a measure should be based on adequate psychometric methods and follow the *Standards for Educational and Psychological Testing* (American Educational Research Association et al., 2014). By doing so, greater rigor can be obtained when developing a new instrument (DeVellis et al., 2021) (e.g., development of items and interpretation of scores) or adapting an existing instrument (International Test Commission, 2018). As highlighted by Festinger (1957), researchers should also explore the possibility of weighting the relevance of items. This is important

because individuals can give different weights to the same aspect (e.g., environmental friendliness) depending on the transport mode, sociodemographic characteristics, or local mobility context.

Second, researchers should be aware not only of how behavior and attitudes can be measured separately, but also of how such measures can be combined to draw a meaningful inconsistency measure. Although a categorical measure brings the idea of classifying individuals into consistent or inconsistent users as discussed in Section 2, which is a necessary condition for such magnitude of inconsistency measure, it is not sufficient according to Festinger (1957). A magnitude of inconsistency measure should bring the idea of intensity and continuity.

While no previous discussions on this matter have been identified in the literature, combining attitudes and behavior measures to create a magnitude of inconsistency should be approached with caution. Before proceeding to summarize the main characteristics that a measure of inconsistency magnitude should have and the challenges associated with this, it is important to state that each individual has an associated behavior for each transport mode under analysis (e.g., the frequency of using the bus), and attitudes toward that mode. Thus, a distinct magnitude of inconsistency measure could and should be calculated for each mode, which is often not considered in several studies available in the literature (see De Vos, 2018; Hu et al., 2023; McCarthy et al., 2021; Mella Lira & Paez, 2021; Pani et al., 2023; Stark et al., 2019; Ton et al., 2019; Ye & Titheridge, 2019; Zarabi et al., 2019).

The first characteristic of a measure of inconsistency is that it should ideally represent the nature of the consistency or inconsistency. This distinction includes two types of individuals: consistent users, who frequently use a mode they have positive attitudes toward, and consistent non-users, who do not use a mode they have negative attitudes toward. It also includes two types of inconsistent individuals: inconsistent users, who frequently use a mode they have negative attitudes toward, and inconsistent non-users, who do not use a mode they have positive attitudes toward. In this way, such a measure could assist policymakers in targeting interventions aimed at changing either behavior and/or attitudes and evaluating the effectiveness of these policies.

As discussed, the second aspect of such a measure is the idea of intensity. However, simply combining the behavior- and attitude-related intensities to develop a magnitude of inconsistency is not straightforward because there is a subtle difference on how they are conceived. It relies on the idea that such a negative behavior does exist; people do or do not perform some behavior. This is often represented by a zero-bounded measure (e.g., frequency of mode use, weekly travelled distance/time with a mode), where positive values represent behavior intensity, and zero means no behavior. Attitudes, on the other hand, can be either positive or negative.

Consider that a measure of inconsistency is proposed based on a simple difference function between behavior and attitudes, where positive values of the magnitude of inconsistency would refer to the intensity of consistency between attitudes and behavior, while negative attitudes refer to an intensity of inconsistency between them. In this case, such a function would result in potential incompatibility with the theory. For example, if an individual has negative attitudes toward cycling but uses it frequently, then a positive behavior minus a negative attitude would yield a positive magnitude of inconsistency, indicating a consistency even though it represents a cognitive inconsistency. This example shows that researchers should carefully consider how to combine both behavior- and attitude-related measures in order to keep the fundamentals of an ideal magnitude of inconsistency measure while being coherent with the theory.

4.3. Discussions on the conceptualization of the cognitive dissonance state

De Vos (2018) showed that individuals who adopt modes consistent with their attitudes have higher levels of satisfaction than those of inconsistent ones. In addition, De Vos (2019) proposed a conceptual model that considers travel mode inconsistency as a mediator between travel satisfaction and travel mode choice or mode-specific attitudes, creating a rationale that associates travel satisfaction with CDS. This is also the case for many other studies (An et al., 2022; Hu et al., 2023; McCarthy et al., 2021; Ye & Titheridge, 2019; Zarabi et al., 2019).

However, there are some issues in assuming travel satisfaction as a proxy to CDS. According to Vaidis and Bran (2019), it is unclear whether the CDS consists of a specific state or can be expressed by emotions. For instance, Elliot & Devine (1994) developed the dissonance thermometer, a tool for measuring cognitive dissonance by answering a self-reported affective experience. They found that CDS may be a distinct aversive feeling. Meanwhile, Sweeney et al. (2000) proposed a different CDS scale based on significant evidence that also comprises emotional components.

Bran and Vaidis (2020) conducted a study to explore the CDS based on the Pleasure-Arousal-Dominance Model, which is often used to measure the impact of stimuli or environmental features on affective states. In particular, the authors applied the hypocrisy paradigm by inducing participants to support a norm and then recalling their behavior in instances violating that norm. As a result, participants in the hypocrisy condition presented less pleasure than those in the control condition, but no significant effects regarding the arousal and dominance scores were found. A similar strategy was employed in transportation research by Gauld et al. (2021) to assess the use of smartphones by young people while driving.

The problem regarding the nature of CDS is also an issue in travel behavior literature. Table 1 shows how different research have considered CDS. While some authors defined CDS as psychological tension or discomfort, others considered it as feelings of discomfort. In practice, a few papers also established subjective well-being as a proxy for CDS (Mella Lira & Paez, 2021; Stark et al., 2019). It shows that understanding the meaning of CDS and how it can be measured has not been thoroughly investigated.

It is important to note that several travel-related emotions have been investigated in travel behavior research alternatively to satisfaction such that the evidence of their influence on mode choice should be a starting point to search for the nature of CDS. Fan et al. (2021) found a positive correlation between travel happiness and transport mode consistency. Mella Lira and Paez (2021) investigated travel mode inconsistency concerning affective values such as freedom, enjoyment, happiness, poverty, luxury, and status, and show that inconsistencies varied among people with different socioeconomic characteristics.

Ma et al. (2021) found that regular bicycling is negatively associated with psychological distress and positively associated with life satisfaction, thus increasing mental well-being. Jin et al. (2022) analyzed the effects of commuting time on the perceived stress of workers according to commuting patterns and modes, and found that perceived stress is likely to be lower among public transport (PT) users, despite having longer commutes than cars. Although some of these studies did not focus on CDT, they may provide insights into potential psychological states or emotions that could arise from cognitive inconsistency.

Another argument against the assumption of travel satisfaction as a proxy for CDS is due to the evidence suggesting that factors such as commuting time and mode also influence travel satisfaction (Choi et al., 2021; De Vos et al., 2022; Gerber et al., 2020; Li et al., 2022; Ma et al., 2021; Tao et al., 2022; Yang et al., 2022). This poses a particular challenge as it is essential to establishing a causal relationship between cognitive inconsistency and the CDS. Without identifying the presence of a CDS, it becomes challenging to assess if inconsistent attitudes or behaviors lead to changes in individuals. This is vital for promoting policies grounded in the CDT framework, as interventions aimed at reducing cognitive inconsistency may prove ineffective if such inconsistencies do not engender significant psychological discomfort.

Brathwaite and Walker (2018) highlight three lessons from causal inference literature that fit in the assessment of CDT as well as its correlation to the magnitude of inconsistency. First, researchers must be explicit about the assumption in drawing their conclusions (e.g., CDS is caused by a certain level of magnitude of inconsistency). Second, researchers could make fewer or less robust statistical assumptions in their models (e.g., adoption of non-parametric and semi-parametric models that capture realistic scenarios). Third, the validation of models must use out-of-sample data (e.g., use actual results for post-evaluation to validate model outcomes).

According to the authors, such studies require research designs that are not usual in transportation research. Beyond the use of post-validation studies, travel demand modelers should leverage 'natural experiments' and highlight credible observational studies, such as well-executed regression discontinuity and difference-in-difference designs. Particularly concerning the investigation of CDS and the magnitude of the inconsistency relationship, researchers should endeavor to develop randomized controlled trials (RCT) to enhance the credibility of both analysts and the public, thereby improving policymaking despite the practical and ethical issues involved.

When it is not possible to apply these designs, the adoption of longitudinal structural models is highly recommended, particularly because of subjective variables such as attitudes. This allows researchers to study both average changes of a construct between individuals across the population and the stability of differences within the same individual over time (Chorus & Kroesen, 2014; Geiser, 2021).

Furthermore, it would be important to develop experiments to identify cases where magnitude of inconsistency does not suggest a CDS. Experiments could be conducted to assess the contexts and the critical levels that lead individuals to develop or perceive CDS. Bran and Vaidis (2021) found that not every situation of existing minor inconsistencies leads to a CDS. In their view, further evidence is needed such as self-relevance or conflicting behavior responsibility for this to occur. In travel mode choice, it may be the case of exploring the effect of accessibility and affordability levels on mode captivity or habitual behavior, which may create different situations of cognitive inconsistencies but not necessarily the CDS (Humagain et al., 2021).

4.4. Resistance to change behavior and attitude

Despite its importance to the CDT, the constructs of resistance to changing behavior and attitudes have been neglected in the transportation literature. This gap may stem from the lack of connection between these constructs and the established aspects of travel choice modeling, such as the built environment, social and subjective norms, accessibility, affordability, and generalized travel costs. Establishing clear links between these constructs and the well-known factors may help demonstrate their relevance in the transportation domain. In the following sections, we explore how these two constructs are implicitly addressed in the transportation literature, often hidden within their multifaceted aspects.

4.4.1. Resistance to change behavior

Although people experiencing travel mode inconsistency that results in the CDS may be motivated to adjust their behavior, this may not occur because of several external and/or personal factors. From the CDT perspective, the combined effect of these factors is referred to as resistance to behavioral changes usually referred to as barriers in using transport modes. Susilo and Cats (2014) defined user profiles such as female, low-income, children, young, and elderly travelers, and characterized the users' main travel barriers and translated them into design and operational transport-related variables subject to policy interventions.

De Vos (2018) identified four elements that can prevent an individual from choosing the mode with the most positive attitudes (preferred mode): (i) the lack of travel-related skills, including physical disabilities and health conditions, and difficulties in understanding the PT routes and schedules; (ii) low quality of travel options, which is related to the lack of cycling infrastructure; uncomfortable, and overcrowded PT with several stops, and low frequency and reliability; (iii) the presence of travel barriers, such as driving license requirements, the presence of slopes, low levels of accessibility and affordability, car-free zones, and limited parking spaces; and (iv) travel habits, when individual choices are mainly based on past behavior and no longer on attitudes and preferences. Zarabi et al. (2019) also explored some of these aspects, while investigating their effects on travel satisfaction.

Most of the abovementioned barriers are subject to policy interventions known as *hard measures* (Bamberg et al., 2011), aiming at directly impacting an individual's freedom of choice, for instance, constraining car use and parking, or building more infrastructures such as the cycling and/or rail network. They can also influence travel cost or service level of a specific mode to promote competition among alternatives, such as congestion charging measures, monetary incentives for bicycling, or subsidies for PT (Abou-Zeid & Fujii, 2016; Tsirimpa et al., 2019; Yang & Tang, 2018).

In terms of modal choice, resistance to changing behavior must be considered individually for each mode of transport conditioned

both by its intrinsic characteristics and the local characteristics of mobility and accessibility. While the former relates to individual aspects, the latter reveals the interdependence of constraints of adopting modes. In some scenarios, such as in rural areas, the intrinsic characteristics of individual motorized modes lead to high levels of resistance to changing behavior because there is no competitive alternative. However, in most urban scenarios, changing conditions on alternative modes can be enough to reduce the resistance to changing behavior. This is the case when a new line of metro is built, so that the resistance to changing from car to metro will likely decrease.

In common, these examples show that resistance to changing behavior is highly related to the competitiveness of alternative modes. Providing sufficient infrastructure for desirable transport modes and creating barriers to undesirable behaviors will affect resistance to changing behavior levels. Such considerations, although important, are too simplistic.

Despite hard interventions influencing behavior change, people may keep their choices regardless of the proposed measure (Bamberg et al., 2011). This may be a consequence of habitual behavior, which exists when little information, if any, is processed during the decision-making process (Gärling & Axhausen, 2003). This has been a topic of discussion in travel behavior research (Asgari & Jin, 2020; Bamberg et al., 2003; Chen & Lai, 2011; Daramy-Williams et al., 2019). In this scenario, if the current behavior is not desirable from the point of view of local planning, habitual behavior could be broken by inducing a cognitive inconsistency to these individuals.

Additionally, people may present negative attitudes toward changes in their lives, contributing to maintaining their *status quo* (Khaw et al., 2022). From this perspective, resistance to change can be defined as a three-dimensional attitude separated into three components: affective (e.g., angry, anxiety about a possible change), cognitive (doubts about the genuine needs or individual benefits), and behavioral (complaining about the change and trying to convince others in the opposite direction). On many occasions, this is influenced by an individual's personality and the environmental context (Amarantou et al., 2018; Oreg, 2006).

Although this concept has few applications in transport literature, the inclusion of such a variable is controversial. Nordfjærn and Rundmo (2015) found that resistance to change behavior significantly contributed to the explained variance of accepted transport push measures. Gao et al. (2019b) showed that the factors related to the psychological resistance to change influencing mode shifts of car users are comparatively greater than the influence of such factors on metro users. On the other hand, Nordfjærn et al. (2014) showed a weak relation between resistance to change and cognitive intentions of using PT. Finally, Murtagh et al. (2012) provided evidence of the role of self-identity threats in resistance to change.

Studies on the effects of life events on travel behavior have also provided important insights into resistance to behavior change (Gao, Kamphuis, Ettema, & Helbich, 2019a; Janke & Handy, 2019). Although their main focus is on interrupting habitual behavior, life events may also influence negative attitudes toward general changes. Although such events cannot be targeted by policy interventions, they are relevant to understanding how resistance to behavior change can vary across different life stages. For instance, childbirth is correlated with an increase in resistance toward active modes and PT, and decrease in resistance to shift to cars, while moving to a Transport Oriented Development neighborhood may reduce resistance to choose PT (Clark et al., 2016). These examples provide insights into how population segmentation and integration of land-use policies affect resistance to travel behavior changes alongside mobility-related interventions.

According to the CDT, people are likely to change their behavior if the magnitude of resistance to behavior change is lower than the magnitude of resistance to attitude change in the presence of a CDS (Festinger, 1957). A question that remains unanswered is whether a single indicator of the degree of resistance to behavior change can be created to compare it with inconsistency, or if each component of resistance can be individually considered when testing the conceptual model of CDT depicted in Fig. 2.

4.4.1.1. Resistance to change attitude. Although hard transport policy measures can influence people's attitudes toward different travel modes in the long term by enhancing service levels or creating barriers to the use of a travel mode (van Wee & Kroesen, 2022), strategies to change attitudes toward a mode are related to soft transport policy measures (Bamberg et al., 2011). These refer to psychological strategies, such as marketing public transport or active modes with mass advertising and awareness campaigns promoting their benefits. The goal is to persuade people to voluntarily choose a mode over another by influencing their attitudes.

From Table 1, Tertoolen et al. (1998) is the only example that directly addresses this issue, which induced both environmental and financial awareness to evaluate changes in mode-related attitudes. They found that people may not change their environmentally related attitudes as they claim that others are more guilty than themselves. Additionally, they found that when behavior and attitudes are not in line, attitudes are more likely to change. Individuals would only change their behavior if environmentally friendly behavior was not disadvantageous and if social norms are positive toward it.

Anagnostopoulou et al. (2018) presented a review paper on persuasive technologies for sustainable mobility including several strategies such as challenges and goal setting, self-monitoring and feedback, tailoring, social comparison, gamification and rewards, suggestions, framing, reduction, tunneling, simulation, and cooperation. Attitude change was examined in 11% of the reviewed studies, with most of them yielding successful results. Esztergár-Kiss et al. (2021) demonstrated the applicability of reduction, tunneling, suggestion, personalization, and simulation strategies. However, Sivasubramaniyam et al. (2021) highlighted the ineffectiveness of the self-persuasion strategy in changing attitudes toward car use.

To analyze the reasons some strategies for attitude change fail, one can assess the degree of resistance to persuasion (Bonetto et al., 2019). One popular approach is the assessment of individuals' metacognition, i.e., the study of thinking about thinking. In this context, researchers are focused on measuring individuals' perceptions of their own susceptibility to persuasion, often employing the Resistance to Persuasion Scale (Knowles & Linn, 2003). As soft transport policy interventions are primarily based on persuasion attempts, understanding the degree of resistance to persuasion across various population segments could provide important insights for

policymakers, helping to avoid ineffective advertising programs.

The study of attitude confidence may also be useful in understanding resistance to persuasion. The conviction of a person regarding an attitude makes it more difficult for attempts at persuasion to succeed (Tormala & Rucker, 2018). According to Tormala (2016), attitude confidence can be increased through experiential input, information accuracy, completeness, relevance, importance, and legitimacy. The same author also argues that uncertainty stimulates interest in and engagement with a message. An optimal persuasion strategy would leverage two insights: using uncertainty to foster message processing and the desire for information and certainty to build attitude strength, promoting consistency between behavior and attitudes.

This construct can aid persuasion strategies in line with the CDT by delivering persuasive messages aimed at increasing attitude uncertainty for an undesired mode, while simultaneously increasing the attitude certainty for desired travel modes to weaken resistance to attitude change. In this manner, attitudes can be more readily altered to create cognitive inconsistencies, and CDS can motivate individuals to align with sustainable transport modes.

Finally, attitude change can occur without direct persuasive efforts, but due to normative features (Bonetto et al., 2019), subjective norms of a social context (Bonetto et al., 2018; Levitan & Visser, 2008), personal values (Blankenship et al., 2012, 2015), or simply over time (Xu et al., 2020).

Piras et al. (2021) brought evidence on the influence of social norms and normative messages on indirect persuasion to choose a specific transport mode. Mella Lira and Paez (2021) revealed that there are significant differences in the affective values toward travel modes in terms of age and income. For instance, active travelers report less discrepancy with respect to freedom, enjoyment, and happiness compared to car users. Although this is true for younger people, it does not hold for older adults. Furthermore, people with higher incomes place greater importance on the luxury and status of cars. These results suggest that travel mode attitudes may change over a lifetime and personal contexts regardless of persuasion techniques.

In conclusion, the mechanisms underlying attitude change from the CDT are not fully understood. More research is suggested to investigate factors influencing resistance to changes in travel-related attitudes, especially to understand how the certainty of attitudes can be reinforced or diminished based on preferred transport policies. Assessing the role of established resistance to attitude scales, like the Resistance to Persuasion Scale (Knowles & Linn, 2003), could offer valuable insights into the application of the CDT framework.

5. Policy implications

The conceptual model illustrated in Fig. 2 offers valuable insights into assessing the effectiveness of sustainable transport policies on individual transport behavior. Drawing on the main concepts discussed in this paper, individuals can be categorized by different transport modes based on their level of cognitive consistency or inconsistency, presence of a CDS or CCS, and degree of resistance to changes in behavior and attitudes.

Several classes can be identified, each related to a specific policy intervention. For instance, frequent car users may have high levels of cognitive consistency, indicating frequent car use, suggesting positive attitudes toward cars and CCS. They can display a low level of resistance to attitude change and a high level of resistance to behavioral change. Determining if these individuals are in a dissonance cycle (Fig. 2) is essential. In the event of a CCS, no change can be expected from these individuals unless a life event occurs or a disruptive transport technology emerges. In such cases, policymaking should aim to induce an inconsistency alongside a CDS to initiate a dissonance cycle.

Suppose that one of the transport planning goals is to reduce car use. If a group of individuals exhibits low levels of resistance to attitude change, effective interventions could initially focus on soft policies (Bamberg et al., 2011), such as providing specific information aimed at reducing their attitudes toward cars. The strategy of Zarabi et al. (2019) was to incorporate individuals' personal values, allowing policymakers to emphasize the negative aspects of car-related attitudes that are most significant to these individuals. The goal is to generate a cognitive inconsistency that triggers a CDS.

However, interventions to change attitudes may not be enough to change their behavior in the long term (Tertoolen et al., 1998). In such a scenario, hard policy interventions could be introduced to limit private vehicle adoption if the individual is a free-choice car user, or some gamification strategies could be implemented to encourage the usage of public transportation (Anagnostopoulou et al., 2018); however, if the individual is a captive car user without other transport alternatives, enhancing the accessibility of public transport or its level of service is essential.

It exemplifies how the population could be divided into more specific categories that could be targeted by policy interventions. This expands the scope of specific strategies and targets in accordance with the specific needs of individuals (Bamberg et al., 2011; Bamberg, 2013). From this perspective, sustainable mobility policies should center on the fundamental premise of CDT: individuals strive to achieve internal consistency. A balance between soft and hard interventions should be managed to prevent long-term cognitive inconsistency and CDS.

Interventions to reduce car use should include restrictions on it, enhancement of PT service levels and accessibility, and persuasion campaigns that convince individuals that adopting sustainable transport modes is indeed beneficial. For instance, consider a low-quality public transport system having captive users who have negative attitudes towards this mode. To obtain consistency within themselves, these users may try to change their behavior soon because of the low quality of the transport service. This context may be linked to the historical fall in demand for public transport (Jin et al., 2019; Maldonado-Hinarejos et al., 2014; Rabay et al., 2021). Therefore, this framework underscores that policymakers should not merely be satisfied with the number of users, but also ensure that they are cognitively consistent users in a CCS by promoting policies to increase their attitudinal levels toward the PT system.

Lastly, the CDT framework is not only beneficial for public policy but also for transport companies aiming to attract more users, especially in new disruptive modes like ride-hailing and on-demand PT. Gentle promotional techniques, such as advertising the

drawbacks of existing modes and the benefits of new ones, can create a cognitive inconsistency and initiate a dissonance cycle in individuals. This can attract their attention to a new service or use similar strategies to improve the service level and retain their clients.

6. Conclusion

This scoping review offers a comprehensive discussion on the application of CDT to mode choice modeling, underscoring the gaps and potential directions for future research. To attain the first objective of this review, we revisited the seminal work of Festinger (1957) supplemented by Vaidis and Bran (2018, 2019) to present a comprehensive perspective of the theory, its constructs, and mechanisms. A concise framework based on five major constructs is presented in Fig. 1. These constructs guided the literature search through the: definition of cognitive dissonance; measurement of cognitive inconsistency; definitions and constructs related to the CDS; and the extent to which resistance to behavior and attitude change have been considered in the literature.

After the literature search and screening process, Table 1 summarizes 18 papers related to mode choice modeling to achieve the second objective of this paper: to identify gaps and suggesting areas for future research in the field. Results indicate that several definitions of the term “dissonance” have been considered. As this ambiguity prevents the development of the theory, we recommend that future studies adopt the definitions provided by Vaidis and Bran (2019), which distinguish between the concepts of cognitive inconsistency and the resulting psychological discomfort.

Several measures have been proposed to assess the magnitude of inconsistency, but most are categorical variables that classify individuals as either consistent or inconsistent users of a specific transport mode. Festinger (1957) emphasized that inconsistencies are not of equal magnitude, and we recommend addressing continuous variables to assess the magnitude of inconsistency. While it might be straightforward to provide a measure for behavior intensity, the same may not be true for indirectly observed variables, such as attitudes. In such cases, Item Response Theory (Ayala, 2022) may be a suitable approach to assess attitudes and create a composite measure of inconsistency magnitude.

Despite the existing papers using travel satisfaction as a proxy for the CDS, it is necessary to establish a causal mechanism between travel satisfaction and the magnitude of inconsistency, which is not supported by the existing literature (Choi et al., 2021; De Vos et al., 2022; Gerber et al., 2020; Li et al., 2022; Ma et al., 2021; Tao et al., 2022; Yang et al., 2022). In this investigation, it is important to note that low levels of cognitive inconsistency might not result in CDS. Therefore, analyzing the degree of inconsistency that leads to a particular proxy for a CDS is crucial to test such hypothesis and avoid false negative correlations. As a result, further exploration is needed to determine what should be considered a suitable proxy for describing the CDS, especially in relation to the role of travel-related emotions.

As mentioned, there is limited knowledge on how to measure resistance to behavior change. Despite identifying several barriers to adopting travel modes, no connection with this CDT construct has been established yet. Similar lack of studies concerning resistance to attitude change has been observed. Future research should delve deeper into the study of persuasion techniques and their related constructs to measure resistance to attitude change (Bonetto et al., 2019). Understanding the factors that make up such constructs is crucial for policymakers, as both soft and hard interventions can contribute to changes in behavior or attitudes toward targeted transport modes.

Addressing these research avenues can contribute to assessing policy implications based on CDT. As demonstrated, the major advantage of adopting CDT as a framework is to classify individuals according to their position at the dissonance cycle. Each individual group may require specific policy interventions aligned with local transportation planning goals.

As the dissonance cycle is time sensitive, longitudinal data are needed to assess attitudinal and behavioral changes, regardless of whether future studies are exploratory in nature or aim to assess the impacts of external interventions. In this context, cross-lagged panel and latent transition models are sophisticated alternatives for performing such analyses (Kroesen et al., 2017, 2023; Kroesen & De Vos, 2020).

This study stands out for adopting a scoping strategy based on PRISMA-ScR (Tricco et al., 2018) to clearly define the objective of the discussion and the method of searching for the analyzed documents, ensuring reproducibility and an objective assessment of the results. In addition, the discussion, definition of concepts, and guidelines for future research avenues exceed the depth necessary for a scoping review, laying the groundwork for conducting a systematic review in the future.

However, this scoping review is not without limitations. While the choice to restrict the search only to the Web of Science repository may have excluded a few important studies for discussion, the overlap among repositories concerning journals with the highest impact factors in travel behavior mitigates this drawback. Thus, future research should consider the inclusion of alternative platforms that contain databases with potentially eligible studies. Additional limitations of this review include the criteria for literature search, such as the date, English language publications, and peer-reviewed papers.

Although our review is limited to travel mode dissonance, it may be useful for gaining insights into other applications of the theory in travel behavior research, such as residential dissonance. The screening process also required a subjective interpretation of how the selected papers intersected with CDT and travel mode choice research. In this sense, the discussion presented in this paper is not intended to be exhaustive, but sufficient to address the current state of the art.

CRediT authorship contribution statement

Lucas Eduardo Araújo de Melo: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Jorge Sinval:** Writing – review & editing, Methodology,

Investigation, Formal analysis. **Cassiano Augusto Isler:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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