

Perspective

Advancing Behavioural Theories in Sustainable Mobility: A Research Agenda

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Abstract: Ensuring that the growing mobility demand is met in a sustainable manner is important for our climate goals, and this would require changes to our current mobility behaviours. Behaviour and behaviour change theories have an important role in informing the mobility behaviour research and practices that seek to achieve these changes, and this paper discusses the application of these theories in both research and practice. Newer and more comprehensive theories have been developed in this area in the last decade, improving the quality of theories available. However, two key challenges of using theories are identified. The great number of theories today makes it challenging when deciding what and when to use them, and the appropriateness of many theories are either too simplistic or too complex. Thus, there is a need to critically review the state of theories in this area and identify ways to advance our application and development of behavioural theories. Here, two suggestions are put forward on how we can address these challenges while advancing the use of theories in mobility behaviour research and practice. First, integrate and summarise multiple, individual theories into a comprehensive and accessible framework for researchers and practitioners. Second, expand this framework beyond behaviour and behaviour-change theories by mapping out their interconnections with theories from other paradigms and disciplines using a systems approach to facilitate a more holistic theorisation.



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1. Introduction

Climate change is now disrupting economies and affecting lives today and will continue to do more in the years to come unless action is taken to reduce the greenhouse gas emissions from human activities that are driving climate change [1]. Goal 13 of the 2030 Agenda for Sustainable Development reflects this with a call for urgent action to combat climate change and its impact. The Paris Agreement, an environmental accord adopted by nearly every nation during the United Nations Framework Convention on Climate Change's 21st Conference of Parties, marked a historic turning point for global climate action through sustainable development with the aim of limiting warming to 1.5 to 2 degree Celsius above pre-industrial levels [2]. At the heart of the Paris Agreement is the nationally determined contributions where each country decides and commits to a climate plan that embodies the country's ambition for reducing greenhouse gas emissions, taking into account its domestic circumstances and capabilities.

It is also understood that emission reductions are taken based on equity and in the context of sustainable development and efforts to eradicate poverty; thus, different country parties would have different nationally determined contributions that reflect their ambition, domestic circumstances, and capabilities [2]. For instance, developed countries like the United States and Australia target to reduce emissions by 26–28% below 2005 levels by 2025 and 2030, respectively. The European Union targets a collective reduction of emissions by at least 40% below 1990 levels by 2030. Other countries have tied their commitments to their economy, such as Singapore, which has committed to reducing emission intensity

(calculated by CO₂ emissions per unit of GDP) by 26% from 2005 levels by 2030 and from 0.176 kgCO₂e/\$ to 0.113 kgCO₂e/\$, and China, which targets to lower emission per unit of GDP by 60–65% from 2005 levels. Some countries have also made a commitment to stabilise their emissions, including China and Singapore's commitment to do so by 2030.

However, understanding the changes in human dynamics globally is crucial for understanding the challenges related to globalization, climate change [3], and most recently, the COVID-19 pandemic. Thus, to achieve these climate action commitments, lifestyle adaptations have to be made and pro-environmental behaviours cultivated. One common environmental behaviour that many countries are focusing on as part of their strategy to reduce or curb their emissions is mobility. Globally, transportation contributed to about 20% of CO₂ emissions globally in 2014, and even as global CO₂ emissions stagnated between 2014 and 2016 [4], transport-related emissions continued to rise and accounted for 24% of emissions in 2019 [5]. This rise in emissions has been noted to be fuelled by a growing oil use in many countries driven by mobility demand [6], and the need for mobility globally will only continue to grow.

That said, in the year of the COVID-19 pandemic in 2020, global CO₂ emissions, including those from private transportation, decreased as how we lived, worked, and played went through unprecedented changes. As global and local travel restrictions were imposed, daily CO₂ emissions globally decreased by 17% by early April 2020 compared to 2019 and half of this reduction is attributed to changes in surface transport use [7]. However, after countries restarted industrial activities and limited reopening of their economies since April 2020, there has been a rebound in CO₂ emissions to pre-pandemic levels [8]. This, for a brief period, showed that it was possible for humans to modify their behaviours and make a significant positive impact on our climate.

Nevertheless, the demand for road vehicles will continue to grow, and thus it will be challenging, if not impossible, to curb without alternative mobility options in place; current policies and interventions are geared towards encouraging the purchase of electric vehicles instead of internal combustion engine vehicles through the means of monetary incentives, largely through subsidies and tax rebates. For instance, in the last decade, the Chinese government incentivised buyers and manufacturers to pivot towards electric vehicles through subsidies and other incentives, and this has been considerably successful, as China accounts for more than half of the world's new electric vehicles today [9,10]. The United Kingdom government has also announced bringing forward the ban of sales of new diesel, petrol, and hybrid vehicles by 2035 from its initial plan of doing so by 2040 [11]. However, monetary incentives are not sustainable in the long run and in China's case, \$58 billion has been spent on electric vehicle subsidies and other policy supports, and the form of government support is changing as subsidies for electric vehicle consumers and producers are reduced or phased out in favour of less costly measures [12]. But would individuals and organisations continue to purchase and use electric vehicles once these monetary incentives are phased out? Using incentives to encourage behaviour change may lead to short-lived effects [13,14], though car purchases and mobility decisions may arguably be driven more by supply-side factors, like the type of cars and mobility modes available to individuals [15]. Nevertheless, this suggests that we need alternative and fiscally sustainable interventions to change mobility patterns and choices, and theories of behaviour and behaviour change are well-placed to support these efforts.

The present article discusses the application of behaviour and behaviour-change theories in the area of mobility for both research and practice. Theory can be defined in different ways, but, here, it is defined as a set of concepts and/or statements that describes a system for what is known of a phenomenon and explains and predicts this phenomenon [16–18]. In this context, behavioural theories “seek to explain why, when, and how a behaviour does or does not occur, and the important sources of influence to be targeted in order to alter the behaviour” [19] (p. 22). Behaviour change theories go a step further to explain the process and stages of behaviour change. The use of theories can help researchers and practitioners identify and utilise levers of change, where small changes

have the potential to lead to larger shifts in behaviour, when planning for behaviour-change research and interventions.

This article is divided into three main sections. First, in the section *The Current State of Theory Use*, the theories of mobility behaviours are briefly discussed, including the shift from theories that explain human behaviour in general and context-independently, to more recent theories that attempt to explain specific human behaviours, such as mobility behaviours. Here, the article suggests that while the newer theories (i.e., the Comprehensive Action Determination Model [20] and the Stage Model of Self-Regulated Behaviour Change [21]) offer a more comprehensive explanation of mobility behaviours, they continue to limit their focal variables to internal ones (e.g., values, attitudes, norms, habit, and knowledge) with limited considerations for external variables. This reflects the need to develop greater understanding and theorisation of how internal and external variables interact, facilitate, and constrain each other to develop a better understanding of mobility behaviours. In the second section, *The Challenges of Using Theories*, the article discusses the ease and challenges of applying the theories we have today for research and practice and some of the implications for theory-building. It is posited that it is time to re-evaluate the theories we use and strengthen them for practice. In the third section, *Forging better Theories*, suggestions on how we might further encourage and foster the use of theories in interventions and policy will be discussed using examples from the growing field of autonomous mobility research, as autonomous vehicles and technologies are predicted to bring transformation in how we travel. The first suggestion is to consolidate our understanding of existing theories into unified frameworks. This helps to demonstrate how different theories are related conceptually to provide an accessible summary and guide that facilitates their application. The second suggests that we expand these frameworks beyond behaviour and behaviour-change theories to map out interrelationships with theories in other paradigms and disciplines using a systems approach that facilitates a more holistic and practical theory for researchers and practitioners.

2. The Current State of Theory Use

Behaviour and behaviour-change theories are commonly applied by researchers when studying mobility behaviour (i.e., choices between different mobility modes) because it elucidates the decision-making process and helps identify antecedents of different mobility behaviours that may then be targeted by interventions [22]. There have been a number of efforts in the last decade to consolidate and review our understanding of the antecedents of mobility behaviours (e.g., [23–25]). These reviews have been useful for helping us identify and evaluate specific antecedents of mobility behaviours. However, these antecedents come from a range of theories and these reviews fall short of explaining the relationships between these antecedents within the complexity of mobility behaviours. For instance, the latest of these reviews by [23] found that 56% of their reviewed studies had used theories to inform their studies and identified eight theories in total, with the Theory of Planned Behaviour accounting for a disproportionate 67% of studies (see Table 1 for a summary). They also observed that many of the theory-informed studies augmented the theories with additional antecedents (e.g., habit and personal norms).

Despite the use of these theories in mobility research and practice in the past three decades, it is surprising that there is a dearth of research looking at how these theories are applied and how effective they are in explaining mobility behaviour. Attempting to begin addressing this need, [26] conducted a review focusing on the use of behaviour and behaviour-change theories in mobility research, and they identified fifteen theories (see Table 1 for a summary and Supplementary Materials for a detailed presentation) that have been used. Similar to the finding of [24], they found that some theories were applied disproportionately more often than others, with seven theories accounting for 80% of the studies in the review and the Theory of Planned Behaviour emerging, once again, as the most widely used theory.

These review findings indicate that some theories are more influential and frequently applied than others, consistent with reviews of theory use in other research areas [27–29]. The theories applied most frequently are those developed before 2000 and are well-established in behavioural science, having also been applied in across a range of domains from health to organisation to environmental research (e.g., Theory of Planned Behaviour, Norm Activation Model, Value Belief Norm Theory, and Theory of Interpersonal Behaviour).

Table 1. Behaviour and behaviour-change theories in mobility research identified by Hoffmann et al. (2017) [26] and Chng et al. (2018) [13].

Theory	Author Theorist (Date)	Number of Studies Using Theory	
		Hoffmann et al. (2017) [26]	Chng et al. (2018) [13]
Theory of Planned Behaviour	Ajzen (1991) [30]	16	14
Norm Activation Model	Schwartz (1977) [31]	6	8
Model of Determinants of Script-Based Driving Choice	Gärling, Fujii, and Boe (2001) [32]	—	3
Value Belief Norm Theory	Stern, Dietz, Abel, Guagnano, and Kalof (1999) [33]	1	3
Theory of Interpersonal Behaviour	Triandis (1977) [34]	1	3
Ipsative Theory of Behaviour	Frey (1988) [35]	2	—
Comprehensive Action Determination Model	Klöckner and Blöbaum (2010) [20]	—	2
Stage Model of Self-Regulated Behavioural Change	Bamberg (2013) [21]	—	2
Identity Theory	Stryker (1980) [36]	1	—
Independence Theory	Kelley and Thibaut (1978) [37]	1	—
Model of Material Possession	Dittmar (1992) [38]	1	1
Model of Action Phases	Heckhausen and Gollwitzer (1987) [39]	—	1
Normative Decision-Making Model	Schwartz and Howard (1981) [40]	—	1
Prospect Theory	Kahneman and Tversky (1979) [41]	—	1
Selection, Optimism, and Compensation Model	Baltes and Baltes (1990) [42]	—	1
Theory of Cognitive Dissonance	Festinger (1957) [43]	—	1
Theory of Cognitive Evaluation	Deci and Ryan (1975) [44]	—	1
Value Attitude Behaviour Hierarchical Model	Homer and Kahle (1988) [45]	—	1

Note: The total number of times that the theories appear in each review adds to more than the number of studies in each review, as the studies may include more than one theory. Hoffmann et al. (2017) had 24 studies and Chng et al. (2018) had 32 studies in their reviews.

One possible explanation as to why the Theory of Planned Behaviour is the most widely used theory for studying mobility behaviour is the relative ease of applying the theory. Its parsimonious theorisation (with five main constructs) makes it relatively easy to apply, especially when there is also clear guidance available from the theorist [46] on how the theory should be used. In addition, its established history of use, also dating back to its precursor, the Theory of Reasoned Action, gives researchers rich examples of how the theory can be applied across a variety of domains and behaviours.

Though these established theories have demonstrated good utility in studying mobility behaviour, there had been an effort in the last decade to revise and update these theories, and this led to the proposal of two new theories: the Comprehensive Action Determination Model [20] and the Stage Model of Self-Regulated Behaviour Change [21].

The Comprehensive Action Determination Model was developed for understanding ecological behaviours, integrating the main assumptions from the Theory of Planned Behaviour, the Norm Activation Model, the Ipsative Theory of Behaviour, and the Construct of Habit, leading to the incorporation of intentional, normative, habitual, and situational influences within the model. An external variable of access was also included in its conceptualisation of situational influences in addition to perceived behavioural control. This acknowledges and incorporates the understanding that one's perception of control and habit is contingent on one's access to resources that facilitate the behaviour, i.e., having access to a car is prerequisite for driving.

The Stage Model of Self-Regulated Behavioural Change was developed to guide systematic development of interventions with an emphasis on the self-regulatory nature of

behaviour change by conceptualising behaviour change in stages with intention deconstructed into a time-ordered sequence of goal-, behavioural- and implementation-intention, inspired by the Model of Action Phases which stresses the deliberative, goal-directed nature of behaviour change. Accordingly, constructs from the Norm Activation Model were integrated as predictors of goal-intention and the constructs of the Theory of Planned Behaviour as predictors of behavioural-intention.

Both theories have built largely on the well-established behaviour mechanisms across a range of theories, and, despite their distinct purposes and theorisations, the emerging evidence from recent studies [20,21,25,47,48] have suggested that they explain mobility behaviour and behaviour change more comprehensively than the established theories. Nonetheless, both theories, like earlier ones, largely continue to limit their focal variables to internal ones (e.g., values, attitudes, norms, habit, and knowledge) with limited considerations for external variables. Thus, we need to move towards developing greater understanding and theorisation of how internal and external variables interact, facilitate, and constrain each other to develop a holistic understanding of mobility behaviour.

3. The Challenges of Using Theories

Explicit use of theory does not guarantee the design of good studies or effective behaviour-change interventions, but, when done well, it makes important contributions towards advancing science and the development of more effective interventions. Theories provide a systematic approach to understanding the complexity of mobility behaviour by reflecting the decision-making process and potential influences and factors leading to particular mobility behaviours [49]. In short, the use of theories helps us make sense of research findings and describe how and why interventions succeed or fail, and theory-informed interventions provide a test of the theory. However, there are two key challenges when using behaviour and behaviour-change theories in mobility research or practice.

The first challenge is that we have a growing number of theories, and choosing an appropriate theory for your research or practice is challenging. While [26] identified fifteen theories in their review, it is plausible that the actual number of theories that were applied but may not have qualified for the review is significantly higher. In the medical field, which has relatively more theoretically-driven research and practice, eighty-three different theories have been identified [28], and a series of tools has been developed to help researchers and practitioners understand and select these theories (e.g., the Behaviour Change Wheel [49] and a resource book describing all eighty-three theories [19]). There is no comparable resource currently available for mobility behaviours. Having comparable tools and resources for choosing, operationalising, and applying the most appropriate theories for mobility research or practice would encourage researchers and practitioners ground their work, interventions, and policies in established theories.

The second challenge stems from the appropriateness of existing theories for mobility behaviours. Despite the many theories, no one theory on its own comprehensively explains mobility behaviour because they are either too simplistic, with key antecedents and change-mechanisms absent (e.g., the absence of habit from the Theory of Planned Behaviour), thus failing to represent the complexity of mobility behaviour, or too abstract such that operationalising the theory in practice proves too challenging. The mobility challenges we face are complex ones, influenced by a constellation of intersecting behavioural, psychological, cultural, socio-economic, social-structural, infrastructure, and policy factors. It is, as [50] termed it, a “wicked problem”, or a problem without neat and simple solution. This has led to an add-on culture when using theories, where researchers select a simpler or more established theory like the Theory of Planned Behaviour and supplement it with additional antecedents (e.g., habit and moral norms) to improve its explanatory power of mobility behaviour.

The newer theories (i.e., the Comprehensive Action Determination Model [20] and the Stage Model of Self-Regulated Behaviour Change [21]) have attempted to strike the balance between being more comprehensive and yet easy to apply, but they do not capture the

complexity of mobility behaviours adequately, as highlighted earlier. The addition of new theories also adds to a growing list of theories. In addition, even if our theories are able to comprehensively elucidate the decision-making process and antecedents of mobility behaviours, the next question about whether they acknowledge and consider the external factors that influence mobility behaviours arises. This limitation was also alluded to in a series of articles and commentaries in *Environment and Planning A* by [51–54].

Perhaps it is time to re-evaluate the theories that we use and, if necessary, prune our overgrowing garden of theories to reduce confusion and avoid duplication of efforts among theory users and to take a different approach that will enable us to capture the complexity of mobility behaviour, including both internal and external factors, without unnecessarily adding to the growing list of theories.

4. Forging Better Theories

From the developments in the use of theories in the last two decades, there is growing trend to move beyond thinking of theories individually to thinking about theories as a collective effort to explain the antecedents of mobility behaviours. This is captured in the oft-invoked Aesop fable that tells that sticks, when bundled up, are not easily broken, but sticks taken singly are easily broken. The same applies to theories. Theories are likened to sticks: individually, they have limitations when explaining behaviours, but, when applied collectively, they are able to explain behaviours more comprehensively by augmenting each other.

Using the developments in autonomous mobility research as a case in point, the recently proposed Multi-level Model on Autonomous Vehicle Acceptance proposed by [55] is one such development (see Figure 1). Their theoretical model was developed following a systematic literature review of 124 empirical studies where 28 predictors of AV acceptance (use) were identified and mapped to established theories (e.g., Theory of Planned Behaviour and Unified Theory of Acceptance and Use of Technology) to identify their relationships before being integrated into a unified framework. In the course of developing the framework, the authors had also added value by theorizing the predictors across two levels (micro and meso) and temporally across four stages of decision-making. Such a framework, though larger and more complex than any existing theories, serves to illustrate how each decision-making antecedent theorized within the myriad of theories is interconnected conceptually within the decision-making process, providing an accessible summary and guide to using theories. Having such a framework addresses the pragmatic challenge of identifying suitable factors and theories to use by researchers and practitioners.

Similarly, such a framework will help researchers and practitioners to identify gaps in our current understanding and theorization of mobility behaviour. For instance, [26] found that most theories focused on explaining and predicting decisions and behaviours, with limited focus on explaining how the conduct of a behaviour might then reinforce or weaken the propensity for a similar behaviour in future. In other words, current theories are largely uni-directional. It is needful to also focus on understanding and improving our theorisation of the circular nature of our behaviours and decision making, i.e., understanding the feedback loop. Currently, most theorisations and models are uni-directional, predicting a decision or behaviour. However, the experience and outcomes following the decision or behaviour would go on to reinforce or weaken one's propensity for a similar decision or behaviours in future. While this can be construed in the construct of habit, which is found in some theorisations and is increasingly popular in studies, the experience post-decision or post-behaviour would also change other important cognitive and emotional antecedents, such as norms and beliefs. This feedback loop (see Figure 2 for an illustration) is currently understudied but would be greatly beneficial when studying and predicting the effectiveness of interventions, policies, and programmes. New findings, including the proposal of new antecedents and relationships, will broaden our understanding and to encourage further use of theories by researchers and practitioners.

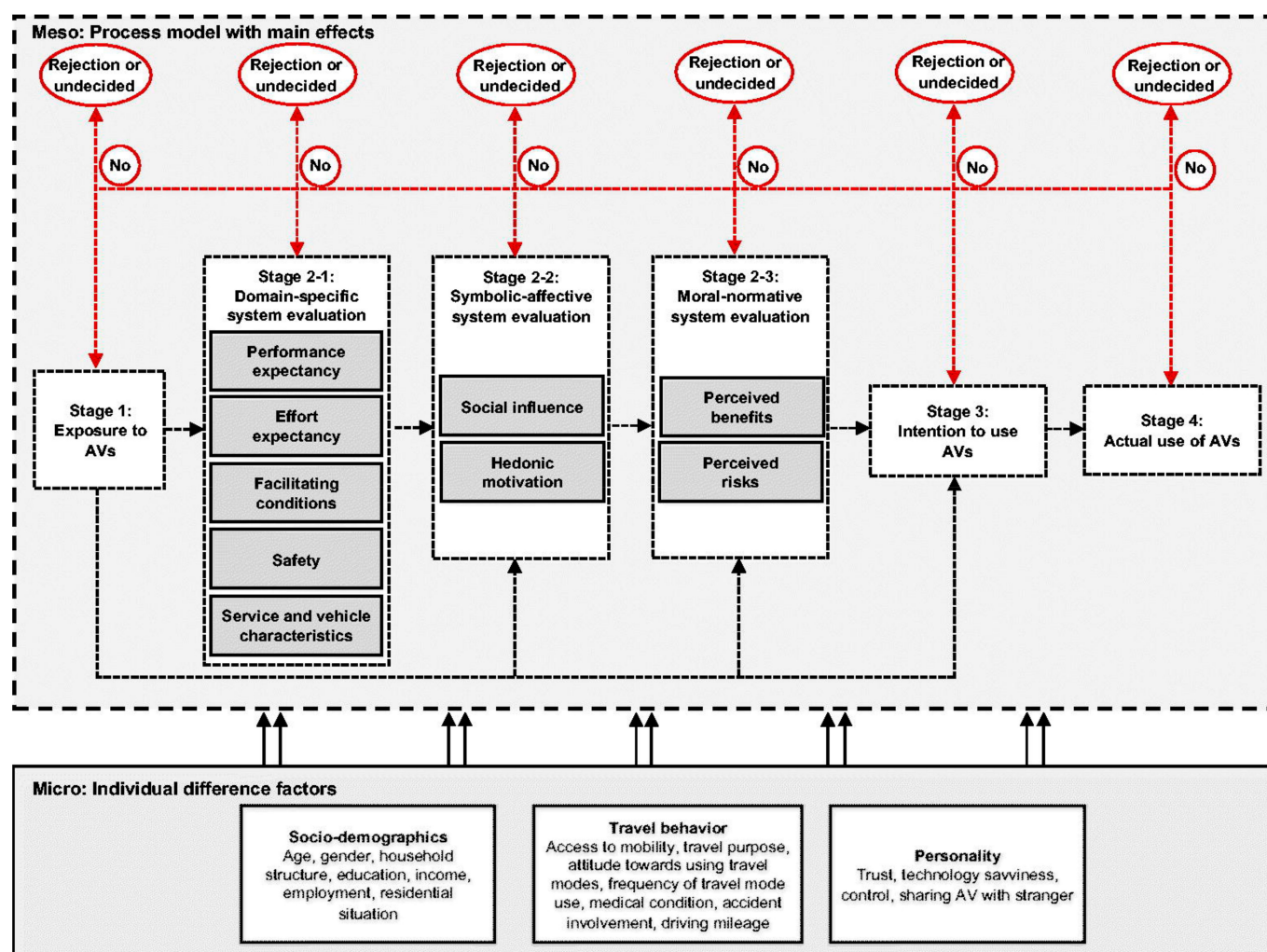


Figure 1. The Multi-Level Model on Automated Vehicle Acceptance (MAVA) proposed by Nordhoff et al. (2019) [43]. Reprinted from ref. [43].

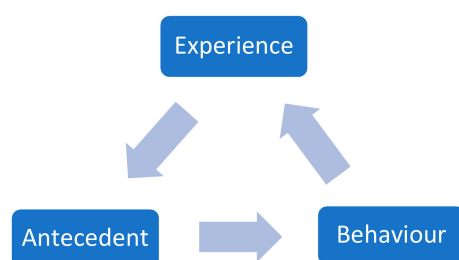


Figure 2. Circular theorizations for behavioural theories.

Behaviour and behaviour-change theories can be further strengthened by thinking beyond the individual and conceptualising these theories within the broader external context, recognising the interconnections and interdependence they share with theories and concepts from different paradigms and disciplines. The experience from the COVID-19 pandemic has clearly illustrated this need, as we observed and experienced unprecedented changes in how we live, work, and play, leading to profound changes in how we interact with our environments and use the physical and social infrastructure and social resources around us. Interdisciplinary research and approaches today would benefit from behavioural theories that interface with other paradigms. This can be achieved by applying a systems approach to investigate how behaviour and behaviour-change theories are

interconnected with theories in other paradigms and disciplines, such as sociology and policy studies [56]. This approach is highly consistent with Lewin's field theory, which describes behaviour as resulting from the interaction between person and environment [57]. Within the policy circle, Paul [58] urged policy scholars almost three decades ago to develop better theories and empirics for understanding policy processes and developed the Advocacy Coalition Framework to address what he perceived were needs in the policy field, including the need for realistic models of the individual rooted in psychology rather than microeconomics and the need for understanding the complexity of subsystems. There has been progress since then, and it continues to be a mammoth undertaking, but it is also one that is needed if we desire to progress towards a more holistic understanding of mobility behaviours and identification of levers for behaviour change.

5. Conclusions

Behaviour and behaviour-change theories have an important role to play in mobility behaviour research and practice, and there has been much progress in improving the quality of theories that are used in this area, particularly through the development of newer and more comprehensive theories. Nevertheless, challenges of using theories in research and practice persist. We have a plethora of theories today, making it challenging when deciding what and when to use them, especially as some underrepresent the complexity of mobility behaviours. Addressing these challenges and to advance the use of theories, this article puts forward suggestions to consolidate our behaviour and behaviour-change theories and existing related knowledge into comprehensive frameworks that provide accessible summaries and guides for researchers and practitioners. These frameworks could also map out interconnections with theories in other paradigms and disciplines using a systems approach to facilitate a more holistic theorization to increase its relevance to practice. Doing so would serve to encourage and support researchers, policy makers, and transport planners as they seek to develop theoretically sound and driven research, interventions, and policies. While this paper is focused on mobility behaviours, the discussions here are equally applicable for other pro-environmental behaviours.

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