Travel behaviour change research: a scientometric review and content analysis

Katherine Pawluk De-Toledo, Steve O'Hern, Sjaan Koppel

1 Introduction

Extensive environmental, economic, health and social benefits can be gained from developing more sustainable transport systems (United Nations, 2016). The International Energy Agency advocates a triple policy approach of "avoid, shift and improve" for encouraging sustainable transport (International Energy Agency, 2020). This includes the avoidance of travel (either partially with reduced trip distances or entirely by encouraging working from home (WFH) and online shopping); shifting travel modes (from private motor vehicle to active travel modes, public transport and carsharing); and making improvements (such as fuel and vehicle efficiencies).

Transport policies have been traditionally approached through the implementation of both 'hard' and 'soft' measures. 'Hard' transport measures include engineering, legal and economic solutions, ranging from infrastructure such as road widening and new bicycle paths to road and parking pricing (Steg, 2003). Alternatively, 'soft' transport measures, also known as a travel behaviour change approach, involve some level of voluntary behaviour change from individuals (Bamberg et al., 2011). Whereby, there is no clear tangible benefit for the behaviour change, such as a decrease in costs. At the most basic level, a travel behaviour change approach uses information dissemination, communication, education, and training to raise awareness to encourage behaviour change (Bamberg et al., 2011). Measures have included: personalised travel

planning (Chatterjee, 2009; Rose & Ampt, 2001); location-based travel plans for key sites such as schools, workplaces and residential settings (De Gruyter et al., 2017; Petrunoff et al., 2015); persuasive technologies such as mobile applications (Anagnostopoulou et al., 2018); events (Rose & Marfurt, 2007) and role model advocacy (Hanna et al., 2018).

A travel behaviour change approach has the potential to complement hard transport measures to develop more sustainable transport systems. Travel behaviour change is a significantly growing field of research which has resulted in a diverse range of theories, behaviours and tools being studied. Consequently, a wide-angled review is critical for synthesising knowledge in this field, to develop evidence for this approach and proposing future research directions.

1.1 Travel behaviour change background

A wide range of behaviour change theories exist. Indeed, a review identified 82 behaviour change theories across the fields of psychology, sociology, anthropology and economics (Davis et al., 2015). The dominant behaviour change theories used in transportation research have been the *Theory of Planned Behaviour* (Ajzen, 1991) and the *Norm-Activation Theory* (Schwartz, 1977) (used both separately and integrated), the *Transtheoretical Model* or *Stages of Change Model*, (Prochaska and DiClemente, 1983), and the *Social Marketing Framework* has also been applied to develop travel behaviour change interventions (Davies, 2012).

The main aim of travel behaviour change interventions has been to encourage more sustainable travel either by directly discouraging private motor vehicle use (Graham-Rowe et al., 2011) or by encouraging alternative travel modes such as active transport (Petrunoff et al., 2016; Scheepers et al., 2014). Previous systematic reviews have reported that behaviour change programmes can decrease private motor vehicle

trips by 5-15% (Brög et al., 2009; Chatterjee, 2009; Möser and Bamberg, 2008; Petrunoff et al., 2016; Scheepers et al., 2014). However, often behaviour change tools have been implemented simultaneously, making it difficult to determine which elements influence the behaviour change (Scheepers et al., 2014). Systematic reviews have highlighted the lack of consistent quality research in this field, including small sample sizes, short study durations, and lack of controlled before-and-after or randomised control research designs (Anagnostopoulou et al., 2018; Chatterjee, 2009; Graham-Rowe et al., 2011; Petrunoff et al., 2016). The current review aims to develop additional insight into the findings of these previous systematic reviews by conducting a wide-angled review, to better understand the evolution and current state of the travel behaviour change research field.

Travel behaviour change is a growing field of research which has resulted in a diverse range of behaviours, theories and tools being studied and applied. Consequently, a wide-angled review is critical for synthesising the growing body of knowledge and to develop evidence for this approach. Recently, scientometric reviews have been conducted to develop overviews of fields of research to capture the evolution of an academic discipline over time and to identify emerging research trends (Chen and Song, 2019). Scientometric reviews have the advantage over other review methods by being able to synthesise a vast amount of data encompassed in a topic-wide review, by both the: 1) volume of topic articles analysed, and 2) number of cited references that can be cross-compared. Consequently, a scientometric review method was seen to be complementary to the previous systematic reviews in the field.

1.2 Scientometric review background
Scientometrics is a science mapping technique that systematically reviews academic literature through the process of domain analysis and visualisation that can be applied to

academic disciplines, fields of research or topics (Chen, 2017; Hu et al., 2014). Within a scientometric review, specific software is used (CiteSpace, VOSviewer, Bibexcel and CitNetExplorer) to analyse "a set of bibliographic records of a research field and generates an overview of the underlying knowledge domain" (Chen & Song, 2019, p.1). Quantitative techniques are applied to analyse the bibliographic records such as article title, author, keywords, journal title and cited references.

A scientometric review shares characteristics of both systematic and narrative literature review methods. Like systematic reviews, it is quantitative-based and therefore is less biased by a researcher's interpretation of results. Scientometric reviews are similar to narrative literature reviews as they both achieve a broad review of literature, unlike the very specific research question addressed by systematic reviews. Insight gained through scientometric reviews is broader than the other review methods, making it effective for overviewing a field, although not as in-depth (Li et al., 2021). Consequently, content analyses have been recommended to complement the retrospective and quantitative nature of scientometric reviews and to provide deeper insight into the type of studies conducted and research methods used (Guo et al., 2019).

Scientometric reviews are increasingly being conducted in the transportation field, to study the field as a whole (Najmi et al., 2017), as well as specific topics, including sustainable transport (Zhao et al., 2020); transportation infrastructure and sustainable development (Wang et al., 2018); specific travel modes (public transport: Heilig & Voß, 2015; electric vehicles: Hu et al., 2014; Secinaro et al., 2020; new energy vehicles: Zhao et al., 2018; hybrid vehicles: Alvarez-Meaza et al., 2019; autonomous vehicles: Gandia et al., 2019; Faisal et al., 2020; and bike-sharing Si et al., 2019). To the researchers' knowledge, a scientometric review has not been conducted on the travel behaviour change field of research.

1.3 Aims

The overall aim of the current study was to conduct a scientometric review of the academic literature published in the travel behaviour change field. To encompass the diversity of travel behaviour change programmes, and allow for the natural boundaries of the research field to be inductively discovered, a broad definition of travel behaviour change was used, where all types of travel (different distances, modes and purposes) were of interest. While extensive research has been conducted on the closely related research field of natural travel behaviour change (for example life course and mobility biographies), these were considered beyond the scope of this review which focuses on intended and deliberate behaviour change due to the implementation of soft policy measures.

Specifically, the review aimed to:

(1) Identify the field's evolution, its main characteristics including key journals, keywords, authors, institutions, countries and cited references, as well as the interdependencies among these characteristics, and

(2) Synthesise the main results into a knowledge map of travel behaviour change research to provide a succinct overview of the field.

(3) To extend the scientometric review method and conduct a content analysis of recent research to identify research trends and gaps in this field and propose a future research agenda.

The study has been organised as follows: the next section outlines the research methodology, including the data source and analysis techniques. The scientometric review results are presented next and are synthesised into a knowledge map of the travel behaviour change research field. Following this, the results of the content analysis are

detailed. The final section provides a conclusion and proposes future research directions.

2 Research method

Figure 1 outlines the key components of the current scientometric review and content analysis.
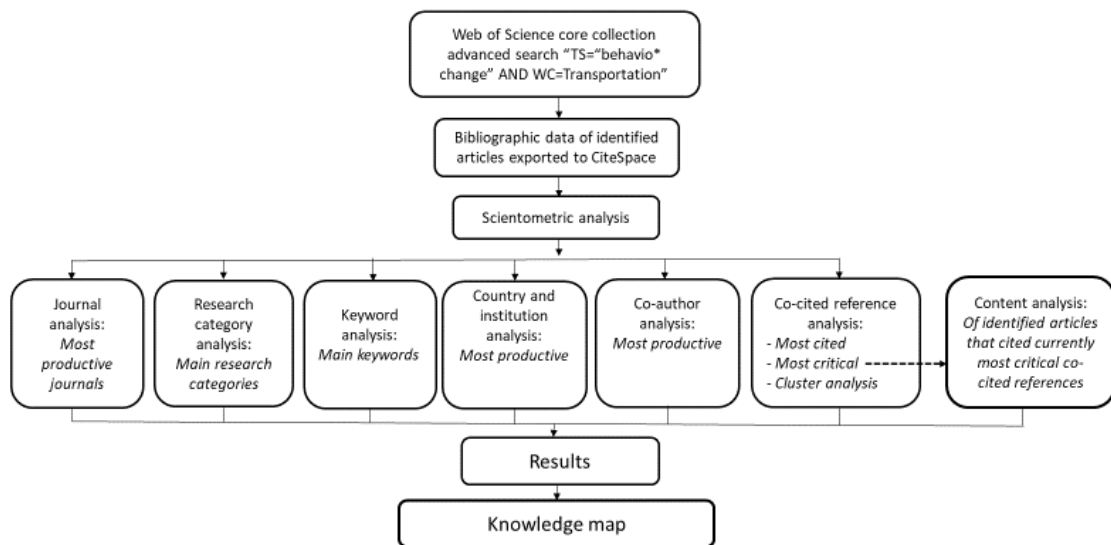

Figure 1. Key components of the scientometric review and content analysis

2.1 Data source

The data source used to obtain the records and accompanying bibliographic data was the Web of Science (WoS) Core Collection (Clarivate Analytics, n.d.). WoS has previously been used by other researchers as it indexes an extensive selection of high-quality peer-reviewed journals and it is compatible with the analysis software (Zhao et al., 2019).

The purpose of the review was to conduct a wide-angled review, and naturally discover the boundaries of the research field. Consequently, the search query was designed to retrieve the broadest range of articles possible. The search query used the Advanced Search function with the topic term (TS) as the search term, which looks for topic terms within the record's fields of title, abstract, author keywords and Keywords

Plus (words generated in WoS based on frequently used words in the titles of cited references). Additionally, the search was limited to the WoS category (WC) of Transportation which includes 51 journals and 98.0 percent are English-language. As the focus of this study was travel behaviour change research, the inputted search term was- "TS="behavio* change" AND WC=Transportation". The * symbol was used to ensure the British and American spelling of behaviour and behavior were both captured in the search. Additional search filters were: only journal articles and a timeframe of 1900-2020.

The WoS search was conducted on 4th March 2020. A total of 323 articles were identified. The bibliographic data for each article was extracted from WoS and imported into the data analytic and visualisation software program CiteSpace II (Chen, 2017, 2016, 2006; Chen and Song, 2019). The bibliographic data included: author's name, institute, country, article name, journal title, research category, keywords, abstract and cited references.

2.2 Data analysis

CiteSpace II v.5.6.R3 was used to conduct the current scientometric analysis (Chen, n.d.). To ensure the most high quality publications were included in the analysis, CiteSpace's g-index default setting was the selection criteria was used, which ranks publications by the number of citations received, as a measure for quality and productivity of academic literature (Chen, 2016). The default scaling factor was applied (k=25) which was developed for CiteSpace to manage the overall size of the network, with the k value proportional to the size of the resultant network (Chen, 2016).

To address the first research aim, a series of scientometric analyses were undertaken using the process outlined in Figure 1. Analyses conducted are detailed in their relevant results sections and aimed to chart the evolution and main characteristics

of the field by identifying: the most productive journals, countries, institutes and authors in this field; the main research categories and keywords; the main (most co-cited) and critical (experienced citation bursts) references; and a cluster analysis of co-cited references. A manual check for different spellings of author and institution names is needed, as different spellings cannot be aggregated automatically in CiteSpace.

To achieve the second aim of the review, the main results from these analyses were synthesised into a knowledge map of the travel behaviour change research, thus creating a summary visual of the field. Finally, to address the third research aim, a content analysis was conducted of recent identified articles that cited current bursting references to understand the research front of travel behaviour change research, identify trends and gaps and recommend a future research agenda. Recent articles were defined as articles published in the three most recent years (2017-February 2020 in this study), a demarcation which has been applied in previous studies (Zhao et al., 2019). Current bursting references from the scientometric review component of the study were used as they are currently experiencing a rapid growth in citations, which indicates the most active area of research (Chen, 2016).

The content analysis involved full-text analysis of the included studies to extract the following data: researcher-related data (authors, institution and country) and study-related data (target behaviour, whether an intervention was studied, if behaviour change was observed, the data collection method, tools applied, presence of a control study group, number of survey waves, the study period and setting, the number of participants and theory used).

3 Results

A total of 323 articles on travel behaviour change were identified and included in the scientometric review and are referred to as 'identified articles'. Figure 2 shows the

number of identified articles published annually from the first record in 1992 to February 2020. The results reveal that while the travel behaviour change field has existed for a long time, the number of articles published has grown substantially in the last decade, mirroring the general growth of transportation publications. However, the growth in this field has outpaced the general transportation field, with 83.9 percent of travel behaviour change articles published between 2011-2020, as opposed to 60.5 percent of the WoS Transportation research category.
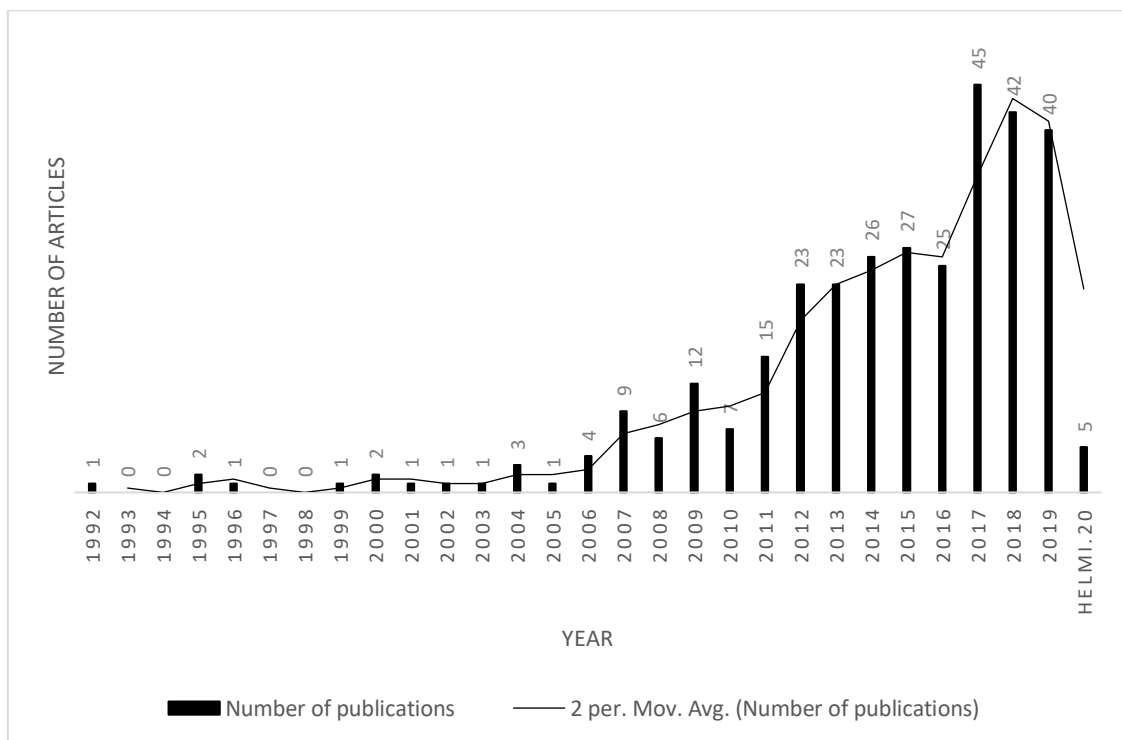

Figure 2. The number of identified articles published per year from 1992 to February 2020 conducted on 4 March 2020 (Source: WoS)

3.1 Published peer-reviewed journal and research category analysis

The 323 identified articles in this study were published in 39 different peer-reviewed journals. Table 1 shows the top ten journals, which published 68.1% of the identified articles, revealing the significance of these journals in the field. In particular, the Transportation Research journal series has been actively engaged in the field with three of its journals in the top ten publishing journals.

Analysis of the research categories involved in a field further highlights which academic disciplines are active in a field. Table 1 shows the ten most published research categories in this field, based on the WoS designation of all the publications into one or more research categories. While the transportation research categories had the highest number of articles, the academic disciplines of economics, health, civil engineering, applied psychology, social sciences, ergonomics, geography and environmental studies were also active in the field, highlighting the multidisciplinary nature of the travel behaviour change field.

Table 1. The top ten journals and research categories (Source: WoS)

Journal name	Number of articles	Per cent	WoS research categories*	Number of articles	Per cent
Transportation Research Part F- Traffic, Psychology and Behaviour	38	11.8	Transportation	303	93.8
Transportation Research Part A- Policy and Practice	34	10.5	Transportation Science Technology	116	35.9
Transport Policy	25	7.7	Economics	89	27.6
Journal of Transport Geography	24	7.4	Public Environmental Occupational Health	58	18.0
Accident Analysis and Prevention	22	6.8	Engineering Civil	40	12.4
Transportation Research Record	18	5.6	Psychology Applied	38	11.8
Journal of Transport Health	17	5.3	Social Sciences Interdisciplinary	35	10.8
Transportation	17	5.3	Ergonomics	34	10.5
Transportation Research Part D- Transport and Environment	13	4	Geography	26	8.1
Journal of Safety Research	12	3.7	Environmental Studies	25	7.7
Total	220	68.1		764	236.5

* WoS assigns all publications to one or more research categories

3.2 Keyword analysis

Journal article keywords are an important characteristic of studying a field of research because they reveal the central topics studied. Figure 3 presents the evolution of travel behaviour change keywords in a time zone view. Keywords with at least three co-occurrences were included, reported in the year first used to show the evolution of keywords over time. The keyword font size reflects the number of co-occurrences. Keywords that were derivatives of the original search term were excluded from this analysis, for example, "behaviour change", "travel behaviour change".

The main keywords included: "attitude"; "cycling" and "bicycling" combined; "intervention"; "climate change", "evaluation" and "habit". Which reveals the topics most studied by researchers in the field. Combined, the keyword results highlight that research has focused on particular aims (climate change, sustainable mobility), research methods (stated preference), theories (social marketing), topics (attitude, intervention, evaluation, habit) and travel modes (bicycling, public transport, active transport). Indeed, the analysis reveals a focus on cycling research in the field, and recently the evolution of combining cycling and walking into the topics of "active travel" and "active transport".
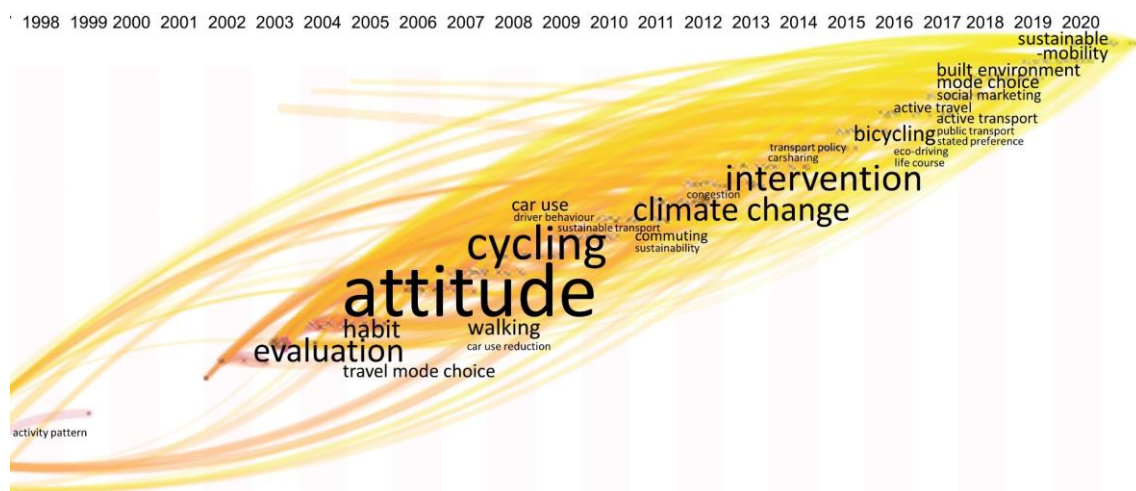

Figure 3. Time zone view of keyword co-occurrence (with at least 3 co-occurrences). Font size reflects the number of co-occurrences. (Source: CiteSpace)

3.3 Country and institution analysis

Country and institution level analysis can reveal if particular countries or institutions dominate a field. Table 2 shows the most productive countries and institutions in the travel behaviour change field, measured by the number of identified articles that they published on the topic. England followed by the USA and Australia dominated the field, accounting for 60.1% of the identified articles. These three main publishing countries could be attributed to the dominance of English-language transportation journals in WoS.

The year of first publication in the travel behaviour change field is also reported revealing that, in general, the countries and institutions with the largest number of publications have been active in this field the longest. The betweenness centrality scores are included, showing the "extent to which paths in the network may go through the node" (Chen, 2016, p.14), and reflect the level of collaboration across countries and institutions (where higher scores indicate higher levels of collaboration). The most collaborative countries were England, Australia, USA, Japan and Germany.

To identify if there were key research groups within the five most productive institutions, the bibliographic data in WoS for each of the journal articles published by these institutions were reviewed. The main research groups identified were the Centre for Transport and Society, University of West England; the Institute of Transport and Logistics Studies, University of Sydney; the Institute for Transport Studies, University of Leeds; xxxx and CTF Service Research Center, Karlstad University.

Table 2. The top publishing countries and institutions (Source: CiteSpace)

Country	No. articles	Centrality score (level of collaboration)	Year of first publication	Institution	No. articles	Centrality score (level of collaboration)	Year of first publication

England	87	0.64	2004	University of West England	26	0.07	2007
USA	57	0.39	1999	University of Sydney	13	0.01	2007
Australia	50	0.43	2006	University of Leeds	12	0.07	2007
Netherlands	27	0.12	2000	xxxx	8	0.01	2007
Germany	17	0.25	2009	Karlstad University	7	0.05	2009
Sweden	17	0.14	2003	University of California- Davis	6	0.01	2012
Japan	16	0.30	2006	Kyoto University	5	0.00	2010
China	16	0.06	2012	University of Cambridge	5	0.01	2015
Canada	14	0.03	2012	Tokyo Institute of Technology	5	0.02	2006
Italy	13	0.03	2002	Delft University of Technology	5	0.02	2014
				Utrecht University	5	0.05	2011
				University of Cagliari	5	0.00	2011
				Queensland University of Technology	5	0.00	2011

3.4 Co-author analysis

Co-author analysis in CiteSpace examines the collaboration of authors, the co-occurrence of authors cited together to establish a network and identify leading co-authors in a field. The main co-authors in the travel behaviour change field are reported in Table 3. The co-author's institution (as of March 2020) and country are also included. The most productive author was Kiron Chatterjee at the Centre for Transport and Society, University of West England (England), which is the institute and country found to be most productive in this field. Chatterjee's research fields include travel behaviour, longitudinal data, biographical methods, life course methods and transport planning.

Table 3. Co-author analysis of ten most productive authors (Source: CiteSpace)

Author	No. articles	Institution (as of March 2020)	Country
Kiron Chatterjee	9	University of West England	England
Satoshi Fujii	5	Kyoto University	Japan

Eva Heinen	5	University of Leeds	England
Dick Ettema	5	Utrecht University	Netherlands
Stephen Greaves	5	University of Sydney	Australia
Italo Meloni	4	University of Cagliari	Italy
xxxx	4	xxxx	xxxx
Glenn Lyons	4	University of West England	England
Ben Clark	4	University of West England	England
Peter Stopher	4	University of Sydney	Australia

3.5 Co-cited reference analysis

A key feature of scientometric reviews is the ability to analyse the commonly cited references in a field, to develop an understanding of the intellectual base of a field (Wang et al., 2018). In this study a co-cited reference analysis was conducted, which compares the frequency references were jointly cited (co-cited) by the 323 identified articles. The main and most critical references were identified and a cluster analysis was conducted to develop a thorough understanding of the field. The analyses were conducted in CiteSpace, then the authors' retrieved and reviewed the articles to create the cited reference summaries included in the results sections.

3.5.1 Main references

Analysis of the most highly co-cited references is a critical component of scientometric reviews by identifying the key articles which represent the underlying ideas in a field. The main co-cited references with over ten co-citations in the travel behaviour change field are listed in Table 4. The most co-cited reference was written by Bamberg, Fujii, Friman and Gärling (2011) in which they proposed the *Self-Regulation Theory Framework* for developing policies to encourage a reduction in private motor vehicle use. The second most co-cited article was written by Brög and colleagues (2009) in which they reviewed the IndiMark social marketing approach to encourage mode shift which was trialled globally. The third most co-cited article was written by Cairns and colleagues (2008) in which they evaluated the impact and cost-benefit of large-scale

soft transport policy measures to reduce motor vehicle use. Notably, Sebastian Bamberg at the University of Applied Science Bielefeld, Germany authored three of the most co-cited articles in the field, highlighting his key role in the field.

WoS and Google Scholar citation counts for the most co-cited references were also extracted to better understand the significance of the articles in the academic literature more broadly (Si et al., 2019) (see Table 4). Two articles were found to have higher citations: Chapman (2007) and Anable (2005). Chapman (2007) reviewed policy approaches to decrease emissions associated with motor vehicle use, road freight and aviation. Anable (2005) segmented day trip travellers into groups based on the potential for mode switching, using psychological measures. The high citations reveal that these publications have been particularly influential in broader academic literature, which could be further investigated to understand which other research topics have been influenced.

Table 4. The main co-cited references (Sources: CiteSpace, WoS and Google Scholar)

Author(s) (Year)	CiteSpace co-citations	WoS citations	Google Scholar citations
Bamberg, et al. (2011)	26	167	363
Brög et al. (2009)	14	95	182
Cairns et al. (2008)	13	123	248
Anable (2005)	12	441	993
Bamberg (2013)	12	99	215
Möser & Bamberg (2008)	10	110	237
Chapman (2007)	10	467	1009
Stopher et al. (2009)	10	43	78

3.5.2 Critical references

A citation burst analysis based on Kleinberg's (2002) algorithm was conducted to identify the most critical references which experienced rapid growth in citations, "an

indicator of the most active area of research." (Chen, 2016, p.76). Seven references were found to have experienced strong citation bursts (see Figure 4), the red line represents the length of the burst in years. The citation busts lasted between three to six years, with a time lag of between four to six years from publishing to experiencing a burst. Indeed, similarities can be seen between the most co-cited and the most critical references.

Burst analyses are also useful for identifying current critical articles to understand a field's research front. Two articles were found to be currently experiencing citation bursts: the most co-cited article by Bamberg et al., (2011) and Richter, Friman and Gärling (2011) who identified knowledge gaps based on a review of the effectiveness of soft transport policy measures to reduce motor vehicle use. These two articles are the main underlying research currently informing ideas in this field, and as such are key for understanding the field's research front and will form the basis of the content analysis presented later in this review.

Cited Authors	Year	Strength	Begin	End	Years 1992 - 2020
Rose G, 2001, TRANSPORT RES D-TR E, V6, P95, DOI	2001	3.5734	2007	2009	
Anable J, 2005, TRANSP POLICY, V12, P65, DOI	2005	5.0511	2010	2013	
Chapman L, 2007, J TRANSP GEOGR, V15, P354, DOI	2007	4.5895	2012	2015	
Cairns S, 2008, TRANSPORT REV, V28, P593, DOI	2008	4.9834	2012	2016	
Brog W, 2009, TRANSPORT POLICY, V16, P281, DOI	2009	4.5441	2014	2017	
Bamberg S, 2011, TRANSPORT POLICY, V18, P228, DOI	2011	4.2687	2015	2020	
Richter J, 2011, INT J SUSTAIN TRANSP, V5, P199, DOI	2011	3.6669	2017	2020	

Figure 4. References with citation bursts (Source: CiteSpace)

3.5.3 Cluster analysis

Different cluster analyses can be conducted in CiteSpace; however, based on co-cited references is particularly valuable because unlike clusters based on the original identified articles, it synthesises a broader range of papers into meaningful groups. The cluster analysis was conducted of co-cited references using the CiteSpace algorithm (whereby each co-cited reference can only be found in one cluster) (Chen, 2016). The

structural quality of the results was analysed by checking the modularity Q and silhouette values. Modularity Q values show "the extent to which a network can be decomposed of multiple components or modules" (Chen, 2016, p.16), where values close to 1.00 mean that there are distinct meaningful groupings and below 0.30 there are between cluster links, therefore requiring careful interpretation (Chen, 2016). The silhouette value highlights the quality of clustering configuration, which can range from -1.00 to 1.00, whereby the higher the value, the more similar the cluster members, with 1.00 being the perfect solution, however, attention also needs to be paid to the size of clusters (Chen, 2016). Chen (2016) proposes that meaningful results can be obtained from between 7-10 major clusters with ten or more members with silhouette values >0.70.

In this review, a total of 117 clusters were identified, with a modularity Q of 0.8736 (>0.3) and silhouette value of 0.4377 which is low, likely due to a large number of small clusters. However, the main clusters with over 20 members had silhouette values ranging between 0.758-0.997 (above the 0.7 threshold) indicating that cluster members have a good level of homogeneity for further analysis (see Table 5). Each cluster is labelled by number in descending order of size (#0 is the largest cluster) and topic, which used the loglikelihood ratio (LLR) for cluster labelling, which compares the likelihood of finding a term in one cluster in comparison to another cluster to develop unique labels, which has been used by previous researchers (Si et al., 2019; Zhao et al., 2020).

The eight main clusters (numbered #0-#7) are overviewed in Table 5, including the cluster name, the number of members, most co-cited references and most representative identified articles. The most representative identified articles were from the 323 identified articles that cited the most co-cited references in the specific cluster.

The key cluster articles presented in Table 5 are significant because they reflect the subfield topics, providing a good starting point for developing knowledge about research on these subtopics of the travel behaviour change field. Cluster #0 which focuses on 'Comparative evaluation' is significant because not only is it the largest cluster with 80 members, but also contained nearly all of the most co-cited and bursting references in the field, making it the most critical cluster in the field (Chen, 2016).

Indeed, articles by the most productive authors appear alongside articles unique to specific clusters. Several authors were found to have authored both the most co-cited references as well as the most representative identified articles in a cluster suggesting their integral role in this topic (for example, cluster #2- Chatterjee, Scheiner and Heinen). Indeed, Scheiner's articles (Scheiner, 2020; Scheiner et al., 2016; Scheiner and Holz-Rau, 2013) were found to be representative of different clusters, as both most co-cited reference in a cluster (cluster #2) and most representative identified articles (from the 323 study articles) of two clusters (clusters #2 and #6). Thus, an examination of Joachim Scheiner's (from the Department of Transport and Panning, Technische Universität Dortmund) research would be valuable for understanding travel behaviour change research.

To identify the current research fronts in this field, recent keywords were identified for the clusters (from 2017- February 2020) (see Table 5). Only four of the clusters were found to have recent keywords (Clusters #0, #2, #3, #6). This is in line with the timeline view of clusters which shows that some of the co-cited reference clusters are now inactive, no longer informing current research (see Appendix 1). These recent keywords highlight the research methods, theories and topics that are currently active subtopics within this field. To develop a more in-depth understanding of the status of current research, a content analysis of articles was conducted.

Table 5. Overview of co-cited reference clusters (Source: CiteSpace)

Cluster number & name	Number of members	Silhouette value	Most co-cited references	Most representative identified articles	Recent keywords
#0 Comparative evaluation	80	0.758	(Bamberg, 2013; Brög et al., 2009; Cairns et al., 2008)	(Chatterjee, 2009; Schwanen et al., 2012)	travel plans, car use reduction, action planning, service quality, public transit use behaviour, customer satisfaction, factor analysis, segmentation, discrete choice model
#1 Behavioural economics	48	0.836	(Schwanen et al., 2012; Shove, 2010)	(Avineri, 2012; Waygood et al., 2012)	
#2 Key event	44	0.878	(Chatterjee et al., 2013; Heinen and Chatterjee, 2015; Scheiner and Holz-Rau, 2013)	(Jain et al., 2020; Scheiner et al., 2016)	car ownership, life events
#3 Mobility-management travel app	40	0.906	(Bird et al., 2013; Clark et al., 2016; Ewing and Cervero, 2010; Jariyasunant et al., 2015; Meloni and Teulada, 2015)	(A. Dastjerdi et al., 2019; A. M. Dastjerdi et al., 2019)	cycling adoption, community, cycling program evaluation, multinomial logit model, social rewards, cycling behaviour, technology-based interventions, mechanism, mobility behaviour change support, travel information, need theory, goal-framing theory, structural equation, persuasive technology

#4 Communicative mobility management measure	31	0.971	(Anable, 2005)	(Fujii and Taniguchi, 2006; Garvill et al., 2003)	
#5 Using reward	28	0.966	(Rouwendal and Verhoef, 2006; Small and Verhoef, 2007)	(Ben-Elia and Ettema, 2011)	
#6 Couple household	25	0.972	(Beige and Axhausen, 2012; Müggenburg et al., 2015)	(Scheiner, 2020)	mode change, mobility behavior, residential relocation, intervention, childbirth, intra-household interactions
#7 Carbon reduction	23	0.997			

3.6 Knowledge map

The second aim of this study was to synthesise the results of the scientometric review into a summary diagram of the travel behaviour change knowledge domain (see Figure 5). This diagram presents all the key results and components of this field, including the main journals, research categories, keywords, countries, institutes, authors and co-cited references; critical references; and the main co-cited reference clusters. Combined, all these findings provide a succinct summary of the field of travel behaviour change research.
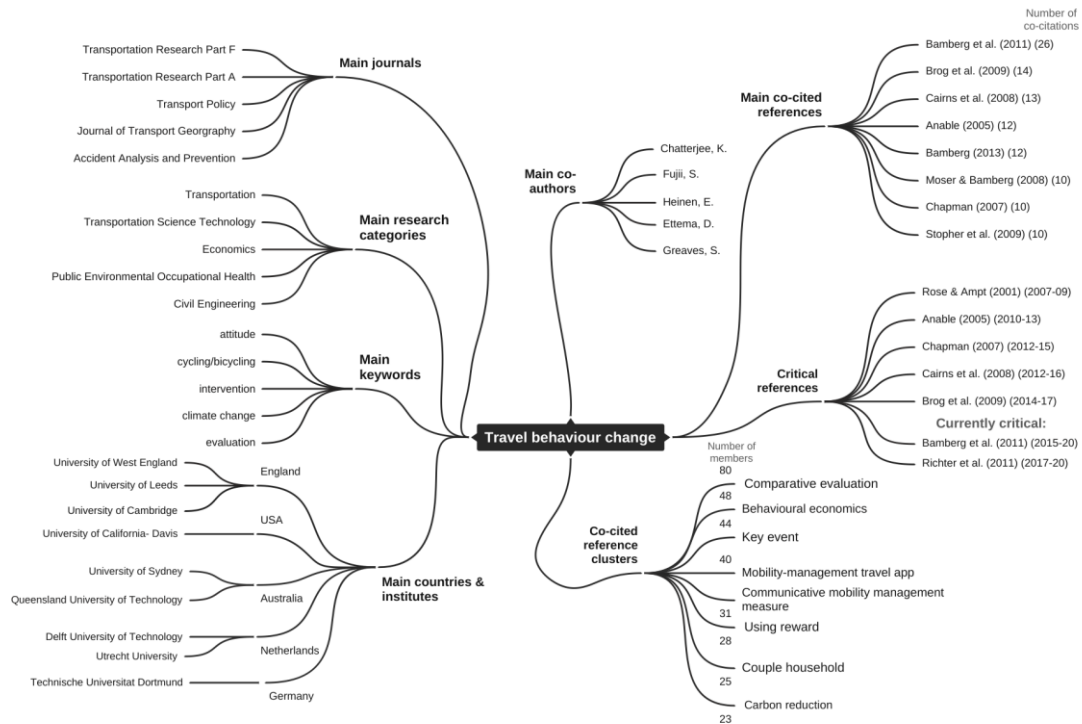
Figure 5. Knowledge map of the travel behaviour change research field

3.7 Content analysis of current research

This study has identified recent keywords (see Figure 3) and recent cluster keywords (see Table 5) to begin to understand the research front in the field of travel behaviour change. A content analysis was conducted to address the study's third research aim- to analyse current research to identify trends and gaps in the field and propose a future research agenda. The content analysis included recent identified articles that cited the two current bursting references (Bamberg et al., 2011; Richter et al., 2011 see Figure 4). Bamberg et al.'s (2011) article proposed *Self-Regulation Theory Framework* to reduce private vehicle use and was the most co-cited reference in the review. Two of the co-authors, Margareta Friman and Tommy Gärling, were also co-authors of the second bursting reference (Richter et al., 2011), which was a review article of previous research results, identifying research gaps and opportunities in soft transport policy knowledge. In addition to being currently the most critical references, they were also in the largest and most critical cluster #0 'Comparative evaluation'; consequently, the content

analysis focuses on the most critical area of current research in the field of travel behaviour change.

Of the 323 identified articles studied in the review, 17 cited these articles recently (between 2017-February 2020, n=7 articles cited both bursting articles; n=8 articles only cited Bamberg et al., 2011; n=2 articles only cited Richter et al., 2011). A content analysis was conducted of the 17 articles to develop an understanding of the current status of research in this field (see Appendix 2).

The main publishing countries were Australia (n=4 articles), Denmark (n=3 articles), and Israel, Italy, Japan, Portugal and the USA publishing two articles each. Studies were most likely to be from Europe (n=10 articles), including Denmark, Italy, England, Spain, Sweden and Germany, however the most researched country was Australia (n=5 articles). The studies focussed on different geographical levels, including: national (n=1), state (n=1), regional (n=1), city (n=5), across several cities (n=2), however most research focused on local areas within a city (n=6).

More than half the articles (n=10) included a theory to underpin their study. The main theory used was the *Stage Model of Self-Regulated Behavioural Change* (n=4) proposed in the bursting reference (Bamberg et al., 2011). This theory was used to examine all stages of change for bike-sharing (Biehl et al., 2019), as well as to examine particular stages of change (pre-actional: Thronicker & Klinger, 2019; actional: Hsieh et al., 2017; and extended the post-actional: Sunio et al., 2018;). Also, the *Theory of Planned Behaviour* (TPB) (Ajzen, 1991) and the *Normative Action Model* (NAM) (Schwartz, 1977) were integrated into two studies (Ryley et al., 2017; Krueger et al., 2018). Alternative theories were also used, including *Goal-Framing Theory* (Dastjerdi et al., 2019b), the *Model of Human Needs* (Dastjerdi et al., 2019a), *Six Persuasion Principles* (Meloni et al., 2017) and the *Four Quadrant Model* (Arroyo et al., 2018).

The majority of studies were travel behaviour change interventions (n=11), in particular field experiments (n=9) and naturalistic studies (n=2). The main behaviour change strategy applied in the intervention studies was information dissemination (n=10). The dominant intervention tool trialled was personalised travel plans (PTP) (n=6), although several studies used technological tools such as mobility apps (Sunio et al., 2018; Weber et al., 2018) and website (Sunio et al., 2018).

The behaviour change focus in the included articles aimed to either: 1) reduce private motor vehicle use (Arroyo et al., 2018; Hsieh et al., 2017; Ma et al., 2017; Mulley and Ma, 2018; Sunio et al., 2018; Thronicker and Klinger, 2019), or 2) increase the use of specific alternative modes, including cycling (Nielsen and Haustein, 2019; Weber et al., 2018), bike-sharing (Biehl et al., 2019), public transport (Skarin et al., 2019), light rail (Meloni et al., 2017; Piras et al., 2018), or bus (Tao et al., 2017). No studies analysed behaviour change interventions that could encourage re-timing of trips or discourage travel entirely, for example, by encouraging telecommuting. Also, the research focused on personal ground transport, no studies focusing on freight or air travel were captured in results.

All studies were quantitative and involved mathematical or statistical analysis and modelling of travel behaviour change. The main data collection method was self-reported traveller survey questionnaires (n=14), which were often conducted online (n=7). Several studies used additional data sources to triangulate results, including national travel survey data (Nielsen and Haustein, 2019); interviews (Ryley et al., 2017) and GPS tracking data (Ma et al., 2017; Mulley and Ma, 2018). Some intervention studies included control groups (n=5), and one study also trialled multiple intervention groups (Hsieh et al., 2017). Most studies collected pre- and post-intervention data, using two waves (n=5) or three waves (n=4) of surveying. Timings of post-intervention surveys were diverse, ranging from two weeks post-intervention (n=1); one month (n=2); three months (n=1); 6 months (n=1); 1 year (n=1) with a maximum of two years post-intervention (n=2) to examine long-term behaviour change. One study that ran two annual post-intervention survey waves found that reduction in motor vehicle trips was immediate, whereas there was a time lag of one year before changes in walking and bus trips, providing a case for longer study timeframes (Ma et al., 2017).

While the majority of intervention studies found travel behaviour change interventions to be effective in changing behaviour (n=9, n=1 was pre-actional study), the results of intervention elements were mainly pooled, and therefore it is difficult to pinpoint which specific elements of a travel behaviour change campaign were most effective. For example, studies used a combination of information dissemination, publicity campaigns, events, personal travel plans and free transport tickets. However, results highlighted that segmented and tailored travel behaviour change interventions were more successful than one-size-fits-all. Nielsen and colleague's study (2019) of a national cycling campaign found that localised intervention activities had a significantly positive effect on increasing cycling participation, whereas a national mass communication campaign did not. Furthermore, targeting a specific segment was found to encourage much higher levels of behaviour change (36%) (Meloni et al., 2017). However, caution is needed with the results of the intervention studies, as they suffered from small sample sizes and representativeness biases. Indeed, participant drop-out is a challenge in multi-wave studies in this field, as is participant self-selection bias with studies relying on opt-in participation.

The scientometric component of this study revealed "segmentation" to be a recent keyword of cluster #0 (see Table 5), and the content analysis adds valuable insight into this keyword. Segmentation research has matured to include: stage-based segmentation (Biehl et al., 2019; Sunio et al., 2018) which showed variance in flexibility to change dependent on the stage of change (Biehl et al., 2019); latent normative beliefs (Krueger et al., 2018); and behavioural, attitudinal, situational and socio-demographic characteristics (Ryley et al., 2017). However, Nielsen and colleagues (2019) expressed concern that while the travel behaviour change campaign resulted in increased cycling numbers, it was not clear which modes individuals had

shifted from (for example pedestrians or public transport users may have shifted to cycling rather than the intended private motor vehicle drivers), calling for closer attention to sub-group modal shifts. Furthermore, Ryley and colleagues' (2017) results revealed that similar travel behaviours occur for different reasons, advocating for research into sub-group differences to ensure appropriate interventions are developed.

4 Conclusion

Travel has extensive economic, environmental, health and social costs (United Nations, 2016). A travel behaviour change approach, combined with hard measures, can encourage more sustainable travel. A wide-angled view of travel behaviour change research was the critical next step to synthesise the diverse nature of the field given the range of behaviours, theories and tools studied, and to develop evidence and future directions for this approach. Therefore, this review aimed to conduct a scientometric review and content analysis to develop a broad understanding of the field of travel behaviour change research to date and to identify future research directions.

A broad definition of travel was used, whereby all types of travel (different distances, modes and purposes) were all of interest in this study. The review identified that, while the field has a long history, with the first article published in 1992, it has significantly grown since 2011. Figure 5 presents the key scientometric results (Aim 1) synthesised into a single diagram, creating a knowledge map of the travel behaviour change research field (Aim 2). To enhance the retrospective and quantitative nature of scientometric analyses, a content analysis was conducted of current research to develop future directions (Aim 3).

The content analysis revealed the behaviours, theories and tools currently researched in the field. It found that targeting private motor vehicle use directly was the main target behaviour. Although, encouraging mode shift particularly to bicycling and

public transport were also studied. Results also highlighted the continued diversity of theories applied in the field. While several theories continue to be applied (SSBC, TPB and NAM), a range of other theories are also currently in use (*Goal-Framing Theory*, *Model of Human Needs*, *Six Persuasion Principles* and the *Four Quadrant Model*). Finally, informational strategies employed through PTP, web and app-based tools are the main tools currently trialled in the field. Based on the trends and gaps in current research identified in the content analysis, there are significant research opportunities in the field of travel behaviour change.

4.1 Research agenda

1. To address Aim 3, we propose six future research directions based on the trends and gaps identified in the 'Content Analysis of Recent Research' Section.**Multiple research methods**- To complement the dominance of participant surveys, we advocate for a broadening of research methods, also previously proposed by other researchers Melia (2015). Where possible data should be collected from multiple data sources, to enable data triangulation to strengthen results and to develop a thorough picture of the experience of behaviour change programmes. Proposed data sources include 1. Participant self-reported pre and post surveys could be complemented with in-depth interviews and or even focus groups to generate new insights and a greater understanding of participant experience in interventions. 2. Observed behaviour data such as GPS, cycling and pedestrian counts or travel data, would provide a valuable comparison to self-reported data. 3. Alternative stakeholder perspectives should be researched, including policymakers, service providers, private companies, behaviour change practitioners involved in interventions whose experience and expertise could add insight into the field. Broadening research methods and developing more holistic

case studies of behaviour change interventions could address limitations of current research, to develop rich and valuable insights into the experiences of behaviour change interventions and develop an understanding of the barriers to change. This omission to date may reflect a publication bias in the field which favours quantitative over qualitative research, nevertheless future qualitative research should be encouraged.

2. **Identify effective intervention components**- For the travel behaviour change field to mature, research needs to go beyond the pooling of intervention results to prove that interventions do result in change. In order for the field to progress, the specific elements that are most effective at encouraging travel behaviour change need to be further explored. Understanding of travel behaviour change could be further enhanced if research were achieved in the next two related research recommendations- 3. locally contextualised research and 4. segmentation research.

3. **Locally contextualised research**- Given the diversity of experiences of transport accessibility throughout a city, the growing body and success of local area studies should be further developed, by contextualising travel behaviour change interventions in local areas. This involves developing behavioural insight of localised travel behaviours; understanding barriers and opportunities for local change; then based on these results create and trial locally tailored interventions. A localised approach could ultimately result in more effective and enduring behaviour change, by being embedded within a local context, hence more sensitive to localised experiences and challenges.

4. **Further development of segmentation research**- The significant and growing body of segmentation research should be further extended. This could be

achieved by both trialling targeted travel behaviour change interventions tailored to different segment preferences, as well as studying different segment responses to interventions. Segmentation based on different stages of change is one approach. For example, further research into the different post-action phase segments identified by Sunio et al. (2018) to encourage longer-term behaviour change which is crucial. Also, reviewing recent citations of Anable's critical segmentation article (Anable, 2005) will reveal alternative segmentation approaches that can be applied.

5. **Long-term behaviour change research-** The ultimate goal of the behaviour change field is to change behaviours for the long-term. As such, this agenda could be pursued by collecting longer (such as one-year post-intervention) and even several waves of post-intervention data. We recognise that this is a challenge with the time constraints of academic research. However, given the number of previous studies conducted in the field, follow-up research could be conducted on previous studies, to see if longer-term behaviour change has occurred. Also, recent research of the post-actional stage of SSBC (Sunio et al., 2018), provides further opportunity for investigating the barriers to maintaining behaviour change in the long-term.

6. **Trip avoidance research**- This is the last but the most urgent research direction. This study revealed that travel behaviour change research currently focuses on reducing private motor vehicle use (either directly or indirectly by encouraging a mode shift in particular to bicycling and public transport). However, trip avoidance measures as evidenced by the COVID-19 experience to date, in particular, the mandatory working from home (WFH) measure, could have an enormous impact on decreasing personal vehicle use, traffic congestion and

environmental costs (Hensher, 2020). We do not know whether post-COVID-19 will provide a turning point to change working behaviour for some sectors and industries forever.

However, validity issues with zero observations in travel surveys as a measure for trip avoidance, has provided a challenge for research on this topic. Nevertheless, there is a body of research on WFH, notably by Patricia Mokhtarian. Although, pre-COVID-19, WFH was considered to be a niche behaviour and the unprecedent widespread adoption due to COVID-19 (Beck and Hensher, 2021) provides new research opportunities. Consequently, more research into trip avoidance behaviours, including WFH is urgently needed to ensure that societies don't simply return to business as usual pre-COVID-19 habits. Or worse, more people will turn to private vehicle use than pre-COVID-19, whereby public transport commuters switch to private vehicle travel, placing even more pressure on highly congested roadways. Consequently, urgent research is needed to improve our understanding of WFH, who could potentially WFH, their willingness and what barriers and opportunities exist to enabling people to WFH from individual, organisational and systems perspectives. Working from home yields economic, social and psychological effects that need to be understood. Even the transport effects may differ from expectations as there may be individual and inter-individual rebound in driving rather than a simple reduction in driving.

4.2 Limitations

Several study limitations should be noted. The study only used the WoS database of peer-reviewed journals as the data source, which overlooked grey literature by practitioners which may have yielded different results. Also, using other academic literature databases could have obtained different results. Additionally, the search query was limited to the WoS research category of transportation, which includes only

transportation journals and are predominantly English-language, which may have overlooked research published in non-English languages. To address potential search query bias, for example a too narrow or too broad a search term in WoS, the cluster analysis was based on the larger number of underlying co-cited references rather than the original identified articles. However, when conducting the co-cited reference analysis self-citations were not excluded, which may be a potential source of bias in the results. There is also a temporal limitation to this study, whereby from the time of conducting the study to article submission an additional 40 papers have been published in the field. In addition, the analysis of current research and future research recommendations were based on a small sample (n=17 articles). However, this was a critical sample, representing the most active area of current research in the field. Although, this is just one part of the travel behaviour change research field, there is scope for analysing current research of other subtopic clusters identified in this study. Also, the focus of this study was on the field of travel behaviour change; therefore, the results cannot be generalised to behaviour change research as a whole or to other specific behaviour change fields. A review of the closely related natural travel behaviour change field (encompassing changes due to life course and mobility biographies), while beyond the scope of this review, would also be valuable. Indeed, replicating this research to the entirety of behaviour change research and other policy areas would enhance behaviour change knowledge.

4.3 Final remarks

Notwithstanding these limitations, the results of this study have shown that scientometric reviews are a useful method for reviewing fields of research by being able to systematically analyse large volumes of data and complex networks. Indeed, valuable insight can be gained by developing a wide-angled view of an academic field for

researchers, policymakers and practitioners. Furthermore, by summarising the results in a single visual diagram, both academics and practitioners will be able to rapidly grasp the essentials of an academic field, enhancing knowledge translation in particular from academia to practice. Summary diagrams are valuable for academics to identify key articles and authors, journals to publish in and potential collaborative partners and for practitioners to identify key institutes, researchers and topics. Finally, this study extended previous scientometric reviews by conducting a complementary content analysis. This additional component enhances the scientometric review method by developing a detailed understanding of current research, forming the basis of a future research agenda.

References

Ajzen, I., 1991. The Theory of Planned Behavior. Organ. Behav. Hum. Decis. Process. 179–211.

Alvarez-Meaza, I., Zarrabeitia-Bilbao, E., Rio-Belver, R.M., de Alegría, I.M., 2019. Mapping scientific and technological patterns: Hybrid vehicles, in: Springer Proceedings in Mathematics and Statistics. pp. 147–158. https://doi.org/10.1007/978-3-030-14969-7_13

Anable, J., 2005. "Complacent Car Addicts"; or "Aspiring Environmentalists"? Identifying travel behaviour segments using attitude theory. Transp. Policy 12, 65–78. https://doi.org/10.1016/j.tranpol.2004.11.004

Anagnostopoulou, E., Bothos, E., Magoutas, B., Schrammel, J., Mentzas, G., 2018. Persuasive technologies for sustainable mobility: State of the art and emerging trends. Sustainability 10, 2128. https://doi.org/10.3390/su10072128

Arroyo, R., Ruiz, T., Casquero, D., Mars, L., 2018. Trip Characteristics Analysis of the Effects of a Travel Behavior Change Program. Transp. Res. Rec. 2672, 146–158. https://doi.org/10.1177/0361198118773184

Avineri, E., 2012. On the use and potential of behavioural economics from the perspective of transport and climate change. J. Transp. Geogr. 24, 512–521. https://doi.org/10.1016/j.jtrangeo.2012.03.003

Bamberg, S., 2013. Changing environmentally harmful behaviors: A stage model of self-regulated behavioral change. J. Environ. Psychol. 34, 151–159. https://doi.org/10.1016/j.jenvp.2013.01.002

Bamberg, S., Fujii, S., Friman, M., Gärling, T., 2011. Behaviour theory and soft transport policy measures. Transp. Policy 18, 228–235. https://doi.org/10.1016/j.tranpol.2010.08.006

Beck, M.J., Hensher, D.A., 2021. Australia 6 months after COVID-19 restrictions part 2: The impact of working from home. Transp. Policy. https://doi.org/10.1016/J.TRANPOL.2021.06.005

Beige, Sigrun, Axhausen, Kay W, Beige, S, Axhausen, K W, 2012. Interdependencies between turning points in life and long-term mobility decisions. Transportation (Amst). 39, 857–872. https://doi.org/10.1007/s11116-012-9404-y

Ben-Elia, E., Ettema, D., 2011. Changing commuters' behavior using rewards: A study of rush-hour avoidance. Transp. Res. Part F Traffic Psychol. Behav. 14, 354–368. https://doi.org/10.1016/j.trf.2011.04.003

Biehl, A., Ermagun, A., Stathopoulos, A., 2019. Utilizing multi-stage behavior change theory to model the process of bike share adoption. Transp. Policy 77, 30–45. https://doi.org/10.1016/j.tranpol.2019.02.001

Bird, E.L., Baker, G., Mutrie, N., Ogilvie, D., Sahlqvist, S., Powell, J., 2013. Behavior change techniques used to promote walking and cycling: A systematic review. Heal. Psychol. 32, 829–838. https://doi.org/10.1037/a0032078

Brög, W., Erl, E., Ker, I., Ryle, J., Wall, R., 2009. Evaluation of voluntary travel behaviour change: Experiences from three continents. Transp. Policy 16, 281–292. https://doi.org/10.1016/j.tranpol.2009.10.003

Cairns, S., Sloman, L., Newson, C., Anable, J., Kirkbride, A., Goodwin, P., 2008. Smarter choices: Assessing the potential to achieve traffic reduction using "Soft measures." Transp. Rev. 28, 593–618. https://doi.org/10.1080/01441640801892504

Chapman, L., 2007. Transport and climate change: a review. J. Transp. Geogr. 15, 354–367. https://doi.org/10.1016/j.jtrangeo.2006.11.008

Chatterjee, K., 2009. A comparative evaluation of large-scale personal travel planning projects in England. Transp. Policy 16, 293–305. https://doi.org/10.1016/j.tranpol.2009.10.004

Chatterjee, K., Sherwin, H., Jain, J., 2013. Triggers for changes in cycling: The role of life events and modifications to the external environment. J. Transp. Geogr. 30, 183–193. https://doi.org/10.1016/j.jtrangeo.2013.02.007

Chen, C., 2017. Science Mapping: A Systematic Review of the Literature. J. Data Inf. Sci. 2, 1–40. https://doi.org/10.1515/jdis-2017-0006

Chen, C., 2016. CiteSpace : a practical guide for mapping scientific literature, Novinka.

Chen, C., 2006. CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. J. Am. Soc. Inf. Sci. Technol. 57, 359–377. https://doi.org/10.1002/asi.20317

Chen, C., n.d. Citespace:Visualizing Patterns and Trends in Scientific Literature. CiteSpaceVisualizing Patterns Trends Sci. Lit.

Chen, C., Song, M., 2019. Visualizing a field of research: A methodology of systematic scientometric reviews. PLoS One 14, e0223994. https://doi.org/10.1371/journal.pone.0223994

Clarivate Analytics, n.d. Web Of Science Core Collection. Web Sci. Core Collect.

Clark, B., Chatterjee, K., Melia, S., 2016. Changes in level of household car ownership: the role of life events and spatial context. Transportation (Amst). 43, 565–599. https://doi.org/10.1007/s11116-015-9589-y

Dastjerdi, A., Kaplan, S., de Abreu e Silva, J., Nielsen, O.A., Pereira, F.C., 2019. Participating in environmental loyalty program with a real-time multimodal travel app: User needs, environmental and privacy motivators. Transp. Res. Part D Transp. Environ. 67, 223–243. https://doi.org/10.1016/j.trd.2018.11.013

Dastjerdi, A.M., Kaplan, S., de Abreu e Silva, J., Anker Nielsen, O., Camara Pereira, F., 2019. Use intention of mobility-management travel apps: The role of users goals, technophile attitude and community trust. Transp. Res. Part A Policy Pract. 126, 114–135. https://doi.org/10.1016/j.tra.2019.06.001

Davies, N., 2012. What are the ingredients of successful travel behavioural change campaigns? Transp. Policy 24, 19–29. https://doi.org/10.1016/j.tranpol.2012.06.017

Davis, R., Campbell, R., Hildon, Z., Hobbs, L., Michie, S., 2015. Theories of behaviour and behaviour change across the social and behavioural sciences: a scoping review. Health Psychol. Rev. 9, 323–344. https://doi.org/10.1080/17437199.2014.941722

De Gruyter, C., Rye, T., van de Graaff, E., Currie, G., Rose, G., 2017. Travel plans for new developments: a global review. Transp. Rev. 38, 142–161. https://doi.org/10.1080/01441647.2017.1322643

Ewing, R., Cervero, R., 2010. Travel and the built environment. J. Am. Plan. Assoc. 76, 265–294. https://doi.org/10.1080/01944361003766766

Fujii, S., Taniguchi, A., 2006. Determinants of the effectiveness of travel feedback programs-a review of communicative mobility management measures for changing travel behaviour in Japan. Transp. Policy 13, 339–348. https://doi.org/10.1016/j.tranpol.2005.12.007

Gabrielli, S., Forbes, P., Jylhä, A., Wells, S., Sirén, M., Hemminki, S., Nurmi, P., Maimone, R., Masthoff, J., Jacucci, G., 2014. Design challenges in motivating change for sustainable urban mobility. Comput. Human Behav. 41, 416–423. https://doi.org/10.1016/j.chb.2014.05.026

Gandia, R.M., Antonialli, F., Cavazza, B.H., Neto, A.M., Lima, D.A. de, Sugano, J.Y., Nicolai, I., Zambalde, A.L., 2019. Autonomous vehicles: scientometric and bibliometric review*. Transp. Rev. 39, 9–28. https://doi.org/10.1080/01441647.2018.1518937

Garvill, J., Marell, A., Nordlund, A., 2003. Effects of increased awareness on choice of travel mode. Transportation (Amst). 30, 63–79. https://doi.org/10.1023/A:1021286608889

Graham-Rowe, E., Skippon, S., Gardner, B., Abraham, C., 2011. Can we reduce car use and, if so, how? A review of available evidence. Transp. Res. Part A Policy Pract. 45, 401–418. https://doi.org/10.1016/j.tra.2011.02.001

Guo, Y.M., Huang, Z.L., Guo, J., Li, H., Guo, X.R., Nkeli, M.J., 2019. Bibliometric analysis on smart cities research. Sustain. 11, 3606. https://doi.org/10.3390/su11133606

Hanna, P., Kantenbacher, J., Cohen, S., Gössling, S., 2018. Role model advocacy for sustainable transport. Transp. Res. Part D 61, 373–382. https://doi.org/10.1016/j.trd.2017.07.028

Heilig, L., Voß, S., 2015. A scientometric analysis of public transport research. J. Public Transp. 18, 111–141. https://doi.org/10.5038/2375-0901.18.2.8

Heinen, E., Chatterjee, K., 2015. The same mode again? An exploration of mode choice variability in Great Britain using the National Travel Survey. Transp. Res. Part A Policy Pract. 78, 266–282. https://doi.org/10.1016/j.tra.2015.05.015

Hensher, D.A., 2020. What might Covid-19 mean for mobility as a service (MaaS)? Transp. Rev. https://doi.org/10.1080/01441647.2020.1770487

Hsieh, H.S., Kanda, Y., Fujii, S., 2017. Reducing car use by volitional strategy of action and coping planning enhancement. Transp. Res. Part F Traffic Psychol. Behav. 47, 163–175. https://doi.org/10.1016/j.trf.2017.05.002

Hu, Y., Sun, J., Li, W., Pan, Y., 2014. A scientometric study of global electric vehicle research. Scientometrics 98, 1269–1282. https://doi.org/10.1007/s11192-013-1067-8

International Energy Agency, 2020. Tracking Transport 2020 – Analysis - IEA [WWW Document]. Int. Energy Agency. URL https://www.iea.org/reports/tracking-

transport-2020 (accessed 11.7.20).

Jain, T., Johnson, M., Rose, G., 2020. Exploring the process of travel behaviour change and mobility trajectories associated with car share adoption. Travel Behav. Soc. 18, 117–131. https://doi.org/10.1016/j.tbs.2019.10.006

Jariyasunant, J., Abou-Zeid, M., Carrel, A., Ekambaram, V., Gaker, D., Sengupta, R., Walker, J.L., 2015. Quantified traveler: Travel feedback meets the cloud to change behavior. J. Intell. Transp. Syst. Technol. Planning, Oper. 19, 109–124. https://doi.org/10.1080/15472450.2013.856714

Kleinberg, J., 2002. Bursty and hierarchical structure in streams, in: Proceedings of the Eighth ACM SIGKDD International Conference on Knowledge Discovery and Data Mining - KDD '02. ACM Press, New York, New York, USA, p. 91. https://doi.org/10.1145/775060.775061

Krueger, R., Vij, A., Rashidi, T.H., 2018. Normative beliefs and modality styles: a latent class and latent variable model of travel behaviour. Transportation (Amst). 45, 789–825. https://doi.org/10.1007/s11116-016-9751-1

Li, Y., Fang, R., Liu, Z., Jiang, L., Zhang, J., Li, H., Liu, C., Li, F., 2021. The association between toxic pesticide environmental exposure and Alzheimer's disease: A scientometric and visualization analysis. Chemosphere. https://doi.org/10.1016/j.chemosphere.2020.128238

Ma, L., Mulley, C., Liu, W., 2017. Social marketing and the built environment: What matters for travel behaviour change? Transportation (Amst). 44, 1147–1167. https://doi.org/10.1007/s11116-016-9698-2

Melia, S., Melia, S., 2015. Do randomised control trials offer a solution to "low quality" transport research? Transp. Res. Part A.

Meloni, I., Sanjust di Teulada, B., Spissu, E., 2017. Lessons learned from a personalized travel planning (PTP) research program to reduce car dependence. Transportation (Amst). 44, 853–870. https://doi.org/10.1007/s11116-016-9681-y

Meloni, I., Teulada, B.S. Di, 2015. I-pet individual persuasive eco-travel technology: A tool for VTBC program implementation, in: Transportation Research Procedia. pp. 422–433. https://doi.org/10.1016/j.trpro.2015.12.035

Möser, G., Bamberg, S., 2008. The effectiveness of soft transport policy measures: A critical assessment and meta-analysis of empirical evidence. J. Environ. Psychol. 28, 10–26. https://doi.org/10.1016/j.jenvp.2007.09.001

Müggenburg, H., Busch-Geertsema, A., Lanzendorf, M., 2015. Mobility biographies: A review of achievements and challenges of the mobility biographies approach and a framework for further research. J. Transp. Geogr. https://doi.org/10.1016/j.jtrangeo.2015.06.004

Mulley, C., Ma, L., 2018. How the longer term success of a social marketing program is influenced by socio-demographics and the built environment. Transportation (Amst). 45, 291–309. https://doi.org/10.1007/s11116-017-9817-8

Najmi, A., Rashidi, T.H., Abbasi, A., Travis Waller, S., 2017. Reviewing the transport domain: an evolutionary bibliometrics and network analysis. Scientometrics 110, 843–865. https://doi.org/10.1007/s11192-016-2171-3

Nielsen, T.A., Haustein, S., 2019. Behavioural effects of a health-related cycling campaign in Denmark: Evidence from the national travel survey and an online survey accompanying the campaign. J. Transp. Heal. 12, 152–163. https://doi.org/10.1016/j.jth.2018.12.003

Petrunoff, N., Rissel, C., Wen, L.M., 2016. The effect of active travel interventions conducted in work settings on driving to work: A systematic review. J. Transp. Heal. https://doi.org/10.1016/j.jth.2015.12.001

Petrunoff, N., Rissel, C., Wen, L.M., Martin, J., 2015. Carrots and sticks vs carrots: Comparing approaches to workplace travel plans using disincentives for driving and incentives for active travel. J. Transp. Heal. 2, 563–567. https://doi.org/10.1016/j.jth.2015.06.007

Piras, F., Sottile, E., Meloni, I., 2018. Modal Share Change following Implementation of Travel Demand Management Strategies. Transp. Res. Rec. 2672, 731–741. https://doi.org/10.1177/0361198118773195

Prochaska, J.O., DiClemente, C.C., 1983. Stages and processes of self-change of smoking: Toward an integrative model of change. J. Consult. Clin. Psychol. 51, 390–395. https://doi.org/10.1037/0022-006X.51.3.390

Richter, J., Friman, M., Gärling, T., 2011. Soft transport policy measures: Gaps in knowledge. Int. J. Sustain. Transp. https://doi.org/10.1080/15568318.2010.490289

Rose, G., Ampt, E., 2001. Travel blending: An Australian travel awareness initiative. Transp. Res. Part D Transp. Environ. 6, 95–110. https://doi.org/10.1016/S1361-9209(00)00015-8

Rose, G., Marfurt, H., 2007. Travel behaviour change impacts of a major ride to work day event. Transp. Res. Part A Policy Pract. 41, 351–364. https://doi.org/10.1016/j.tra.2006.10.001

Rouwendal, J., Verhoef, E.T., 2006. Basic economic principles of road pricing: From theory to applications. Transp. Policy 13, 106–114. https://doi.org/10.1016/j.tranpol.2005.11.007

Ryley, T., Elmirghani, J., Budd, T., Miyoshi, C., Mason, K., Moxon, R., Ahmed, I., Qazi, B., Zanni, A., 2017. Sustainable development and airport surface access: the role of technological innovation and behavioral change, in: Ionescu, G. (Ed.), Transportation and the Environment: Assessments and Sustainability. Apple Academic Press.

Scheepers, C.E., Wendel-Vos, G.C.W., den Broeder, J.M., van Kempen, E.E.M.M., van Wesemael, P.J.V., Schuit, A.J., 2014. Shifting from car to active transport: A systematic review of the effectiveness of interventions. Transp. Res. Part A Policy Pract. 70, 264–280. https://doi.org/10.1016/j.tra.2014.10.015

Scheiner, J., 2020. Changes in travel mode use over the life course with partner interactions in couple households. Transp. Res. Part A Policy Pract. 132, 791–807. https://doi.org/10.1016/j.tra.2019.12.031

Scheiner, J., Chatterjee, K., Heinen, E., 2016. Key events and multimodality: A life course approach. Transp. Res. Part A Policy Pract. 91, 148–165. https://doi.org/10.1016/j.tra.2016.06.028

Scheiner, J., Holz-Rau, C., 2013. A comprehensive study of life course, cohort, and period effects on changes in travel mode use. Transp. Res. Part A Policy Pract. 47, 167–181. https://doi.org/10.1016/j.tra.2012.10.019

Schwanen, T., Banister, D., Anable, J., 2012. Rethinking habits and their role in behaviour change: the case of low-carbon mobility. J. Transp. Geogr. 24, 522–532. https://doi.org/10.1016/j.jtrangeo.2012.06.003

Schwartz, S.H., 1977. Normative influences on altruism. Adv. Exp. Soc. Psychol. 10, 221–279. https://doi.org/10.1016/S0065-2601(08)60358-5

Shove, E., 2010. Beyond the ABC: Climate change policy and theories of social change. Environ. Plan. A 42, 1273–1285. https://doi.org/10.1068/a42282

Si, H., Shi, J. gang, Wu, G., Chen, J., Zhao, X., 2019. Mapping the bike sharing research published from 2010 to 2018: A scientometric review. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2018.12.157

Skarin, F., Olsson, L.E., Friman, M., Wästlund, E., 2019. Importance of motives, self-

efficacy, social support and satisfaction with travel for behavior change during travel intervention programs. Transp. Res. Part F Traffic Psychol. Behav. 62, 451–458. https://doi.org/10.1016/j.trf.2019.02.002

Small, K.A., Verhoef, E.T., 2007. The economics of urban transportation, The Economics of Urban Transportation. https://doi.org/10.4324/9780203642306

Steg, L., 2003. Factors Influencing the Acceptability and Effectiveness of Transport Pricing, in: Acceptability of Transport Pricing Strategies. Emerald Group Publishing Limited, pp. 187–202. https://doi.org/10.1108/9781786359506-012

Stopher, P., Clifford, E., Swann, N., Zhang, Y., 2009. Evaluating voluntary travel behaviour change: Suggested guidelines and case studies. Transp. Policy 16, 315–324. https://doi.org/10.1016/j.tranpol.2009.10.007

Sunio, V., Schmöcker, J.D., Kim, J., 2018. Understanding the stages and pathways of travel behavior change induced by technology-based intervention among university students. Transp. Res. Part F Traffic Psychol. Behav. 59, 98–114. https://doi.org/10.1016/j.trf.2018.08.017

Tao, S., Corcoran, J., Mateo-Babiano, I., 2017. Modelling loyalty and behavioural change intentions of busway passengers: A case study of Brisbane, Australia. IATSS Res. 41, 113–122. https://doi.org/10.1016/j.iatssr.2016.10.001

Thronicker, I., Klinger, T., 2019. Interest into travel-related interventions among urban movers and non-movers. Travel Behav. Soc. 16, 88–98. https://doi.org/10.1016/j.tbs.2019.04.006

United Nations, 2016. Mobilizing Sustainable Transport for Development, Mobilizing Sustainable Transport for Development.

Wang, L., Xue, X., Zhao, Z., Wang, Z., 2018. The impacts of transportation infrastructure on sustainable development: Emerging trends and challenges. Int. J. Environ. Res. Public Health 15, 1172. https://doi.org/10.3390/ijerph15061172

Waygood, O., Avineri, E., Lyons, G., 2012. The role of information in reducing the impacts of climate change for transport applications, in: Transport and Sustainability. pp. 313–340. https://doi.org/10.1108/S2044-9941(2012)0000002015

Weber, J., Azad, M., Riggs, W., Cherry, C.R., 2018. The convergence of smartphone apps, gamification and competition to increase cycling. Transp. Res. Part F Traffic Psychol. Behav. 56, 333–343. https://doi.org/10.1016/j.trf.2018.04.025

Zhao, L., Tang, Z.Y., Zou, X., 2019. Mapping the knowledge domain of smart-city research: A bibliometric and scientometric analysis. Sustain. 11, 6648. https://doi.org/10.3390/su11236648

Zhao, X., Ke, Y., Zuo, J., Xiong, W., Wu, P., 2020. Evaluation of sustainable transport research in 2000–2019. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2020.120404

Zhao, X., Wang, S., Wang, X., 2018. Characteristics and trends of research on new energy vehicle reliability based on theweb of science. Sustain. https://doi.org/10.3390/su10103560
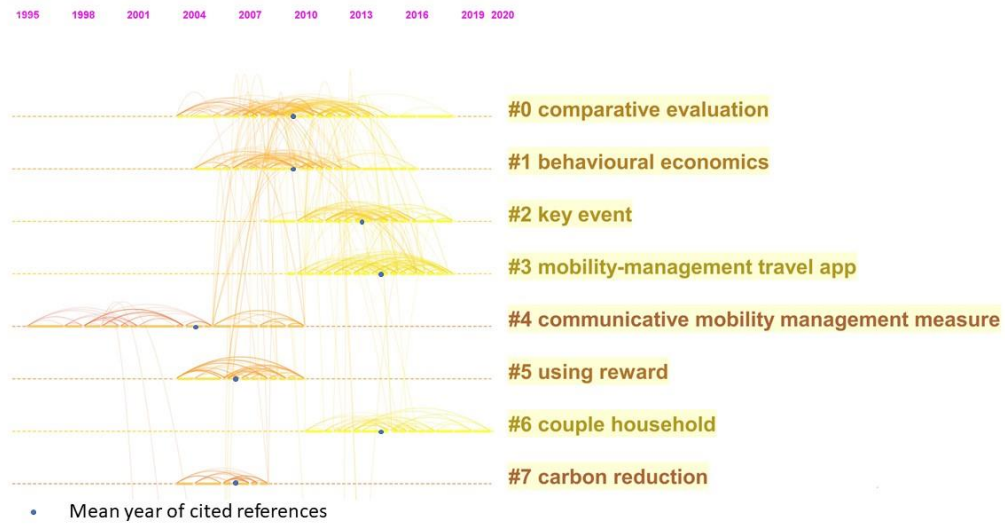
Appendix

Appendix 1. A timeline view of the eight main clusters (with over twenty members) (Source: CiteSpace)

Appendix 2. Summary of 17 articles included in the content analysis

Author(s) (Year)	Institute & country	Target behaviour	Intervention study	Behaviour change achieved	Data collection method	Tools applied	Control group	Survey waves	Study period	Study setting	N (participants)	Theory used
Identified articles that cited both (Bamberg et al., 2011; Richter et al., 2011)												
Biehl, Ermagun & Stathopoulos (2019)	North Western University & Mississippi State University, USA	Bike-sharing	N	n/a	Online survey questionnaire	n/a	n/a	1	February 2017	6 Midwestern states USA	910	SSBC
Skarin, Olsson, Friman, Wastlund (2019)	Karlstad University, Sweden	Public transport	Y	Y	Online survey questionnaire	Free public transport ticket	N	3		Varmland county, Sweden	181	
Piras, Sottile & Meloni (2018)	University of Cagliari, Italy	Light rail	Y	Y	Online survey questionnaire	PTP	Y	2	April 2013 and May 2015	Corridor linking centre of Cagliari with the Cittadella area with University/hospital, Sardinia, Italy	516	

Arroyo, Ruiz, Casquero & Mars (2018)	The Polytechnic University of Valencia & University of Valencia, Spain	Personal motor vehicle	Y	Y	Interviews, mobile phone diaries	PTP, events	Y	2	Autumn 2010 and Autumn 2011	Valencia, Spain	118	Four quadrant Model (Integral theory)
Mulley & Ma (2018)	University of Sydney & RMIT, Australia	Personal motor vehicle	Y	Y	Survey questionnaire & GPS tracking data	PTP	N	3	March-May 2012, 2013 & 2014	Northern suburbs of Adelaide, Australia	104 households	
Ma, Mulley, & Liu (2017)	University of Sydney, Australia	Personal motor vehicle, bus, walking	Y	Y	GPS tracking data	PTP		3	March-May 2012, 2013 & 2014	Northern suburbs of Adelaide, Australia	179 from 113 households	
Meloni, Teulada & Spissu (2017)	University Cagliari, Italy	Light rail	Y	Y	Survey questionnaire	PTP	Y	3	February 2011 & June 2012	Congested corridor between first & third largest cities in Sardinia	109	Six Persuasion principles

**Identified articles that only cited
Bamberg et al. (2011)**

Dastjerdi, Kaplan, Silva, Nielsen & Pereira (2019b)	Technical University of Denmark, Denmark; Hebrew University Jerusalem, Israel; University of Lisbon, Portugal	Multi-modal travel app	N	n/a	Online survey questionnaire	n/a	n/a	1	April-May 2017	Copenhagen, Denmark	822	Goal-framing theory & technophile attitude, community trust & place attachment added
Dastjerdi, Kaplan, Silva, Nielsen & Pereira (2019a)	Technical University of Denmark, Denmark; Hebrew University Jerusalem, Israel; University of Lisbon, Portugal	Multi-modal travel app	N	n/a	Online survey questionnaire	n/a	n/a	1	May-July 2017	Case study- Copenhagen, Denmark	828	Model of Human needs. Environmental attitude, information privacy concerns & perceived difficulties when using the system were also incorporated.

Nielsen & Haustien (2019)	Technical University of Denmark, Denmark	Bicycling	Y	Y	a) National Travel Survey of Denmark & b) Online survey questionnaire	National-Smartphone App, media & social media; Local-services, lotteries, incentives, information, personalise info	N	6	a) July 2010-August 2017 & b) February 2015-June 2017	Denmark	a) 280,000 trips & b) 11,798	
Sunio, Schmoker & Kim (2018)	Kyoto University, Japan	Mobility App	Y	n/a	Survey questionnaire	Website	Y	2	Feb-17	University, Manila, Philippines	241	SSBC
Weber, Azad, Riggs & Cherry (2018)	Georgia Institute of Technology, University of Tennessee & University of San Francisco, USA	Bicycling	Y	Y	App data (including registration data)	Events, Smartphone Apps	N	2 and 3	UK 2015 & 2016, Sydney 2015, 2016 & 2017, Atlanta 2014, 2015 & 2016	Large bicycle events in the UK, Sydney, Australia & Atlanta, USA	66,763 (UK n=49481, Sydney n=11851, Atlanta n=5431)	

Author	Institution	Vehicle			Method				Date	Location	Sample	Notes
Krueger, Vij & Rashidi (2018)	University of NSW & University of South Australia, Australia		N	n/a	Online survey questionnaire	n/a	n/a	1	Apr-15	Five major metropolitan cities across Australia	516	Integrates socio-psychological approaches (TPB, Norm Activation Theory & Theory of Cognitive Dissonance) & lifestyle orientated approach
Hsieh, Kanda & Fujii (2017)	Kyoto University & National Institute of Technology, Japan	Private motor vehicle	Y	Y	Survey questionnaire	PTP	Y	2	March-April 2016	Taipei City, Taiwan	121	SSBC- actional stage

Ryley et al. (2017)	Loughborough University of Technology, University of Leeds & Cranfield University, England; King Abdulaziz University, Saudi Arabia	Ground transport	N	n/a	Survey questionnaire, manager interviews & Civil Aviation Authority data	n/a	n/a	1	June - July 2011	Manchester Airport, England	860	TPB & Norm Activation Model
Identified articles that only cited Richter et al. (2011)												
Thronicker & Klinger (2019)	UFZ Helmholtz & Goethe University Frankfurt, Germany	Participation in behaviour change intervention	Y	n/a	Survey questionnaire & observational data	Ordering mobility package	Y	1		Leipzig, Germany	758	SSBC- pre-actional stage
Tao, Corcoran & Mateo-Babiano (2017)	Chinese University Hong Kong, China; University of Queensland, Australia	Bus	N	n/a	Survey questionnaire (pre-paid response)	n/a	n/a	1	April-May 2013	Nine busway stations, Brisbane, Australia	469	