Documenting the knowledge of pro-environmental travel behaviour research: a visual analysis using CiteSpace

Jiale Zhang and Farzana Quoquab

Abstract

Purpose – *The purpose of this study is to present a comprehensive knowledge mapping and an in-depth analysis of pro-environmental travel behaviour research to better understand the global trend in this field that have emerged between 2000 and 2021.*

Design/methodology/approach – *In this study, a visual analysis of 187 scholarly articles between the year 2000 and 2021 related to pro-environmental travel behaviour (PETB) is presented. Using the knowledge mapping based on CiteSpace it presents the current research status, which contains the analysis of collaboration network, co-citation network, and emerging trends.*

Findings – *The results revealed that the PETB is an emerging topic, which has an increased number of publications in recent years. Though the collaboration network between scholars is dispersed, some countries exert stronger collaboration network. Researchers from England, USA and China have worked more on this topic comparatively. "Pro-environmental norm" is found to be the major concern in regard to PETB, and the theory of planned behaviour (TPB) is the most common theory used by the scholars around the world. Ten articles with the highest citations are found to be the most valuable articles. COVID-19, value orientation, negative spillover, carbon footprints, biospheric and adolescent are some of the latest keywords based on the past two years' literature review, all of which have huge research potential in the future.*

Originality/value – *This study is among the pioneers to shed some light on the current research progress of PETB by using a bibliometric analysis to provide research directions for scholars. Moreover, this study utilized latest data from 2000 to 2021. The studies which are published before and during the pandemic are also incorporated.*

Keywords *Tourists' environmental responsibility, Pro-environmental travel behaviour, Tourism industry, Knowledge mapping, Visual analysis, CiteSpace*

Paper type *Research paper*

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Introduction

Pro-environmental behaviour refers to the behaviour that can minimize the negative impact of individuals' activity on the environment as well as can benefit the environment (Steg and Vlek, 2009; Wu *et al.*, 2021). Likewise, the pro-environmental travel behaviour (PETB) indicates tourists' likelihood to choose the frequency of travel, the destination, the mode of transportation, the tourism products and the activities during the travel for the purpose of environmental protection (O'Connor and Assaker, 2021). Indeed, it exerts a positive effect on the environment of tourism destinations and improves economic performance (Dartey-Baah and Amoako, 2021). Tourism destinations that are more involved in undertaking social and environmental responsibility tend to attract more tourists and improve their profits (Su *et al.*, 2020).

Although the tourism industry contributes to the growth and welfare of the society, it also generates environmental pollution and degradation (Azam *et al.*, 2018; Sadom *et al.*, 2022a, b). In recent

years, with the increased focus on environment and the rapidly growing number of tourists, many researchers started to investigate the notion of tourists' PETB from different country and cultural contexts. Some scholars focused on specific pro-environmental practices, such as low carbon travel, binning behaviour and zero litter initiative (Esfandiar *et al.*, 2020; Hu *et al.*, 2019; Liu *et al.*, 2017). Some other researchers investigated the drivers of pro-environmental behaviours, such as personalized travel planning (Ahmed *et al.*, 2020), use of the Internet (Wu *et al.*, 2019), moral obligation (Wu *et al.*, 2021) and environmental background (Wang *et al.*, 2019).

Since the outburst of COVID-19, the global tourism industry has suffered significantly. With the increased infectious cases and death toll, in order to defeat the COVID-19 pandemic, many countries have implemented strict policies and imposed lockdowns. Such lockdowns and social distancing measures affected the tourism industry seriously because governments closed all travel activities to control the spread of the pandemic. To understand whether there is any change of the travel behaviour of tourists, more scholars have started to explore the effects of COVID-19 on tourism behaviours (Matiza, 2022; Wachyuni and Kusumaningrum, 2020; Yang *et al.*, 2021) and PETB (O'Connor and Assaker, 2021; Urban and Braun Kohlová, 2022). In this study, we have included papers that were published before and during the pandemic, which is unique in nature.

Even after 20 years of research, PETB remains a research topic that is worthy to be further investigated. Indeed, the carbon emission and environmental pollution have always been a difficult problem for the mankind to solve. In this regard, the COVID-19 is regarded as the revenge of nature on humans (Chakraborty and Maity, 2020). Considering this, the present study attempts to understand the issue to its depth and breadth using the knowledge mapping via CiteSpace. This study provides significant research insights for the practitioners to understand the PETB of tourists before and after the pandemic. For example, it is found that, during the pandemic, the tourists became more concerned about their health, and the hotels with the good sanitary facilities became more popular among the travellers (Heydari *et al.*, 2021). Besides, travellers became more environmentally concerned than before (O'Connor and Assaker, 2021). Apart from showcasing the research status of the existing relevant literature, this study also enables scholars to have a general understanding of the future research trend on this topic.

Knowledge mapping has been widely used in many disciplines to provide a systemic and objective overview of a specific research topic (Fang *et al*., 2018). CiteSpace is one of the commonly used software in bibliometric analysis, which is developed by Chen (2004). In the tourism industry, Fang *et al.* (2018) used CiteSpace to analyse climate change and tourism, whereas Li *et al.* (2017) analysed hospitality research using CiteSpace. However, to the best of our knowledge, there is a dearth of review papers on PETB. Though the outbreak of COVID-19 has a huge impact on PETB, there is a dearth of research that focused on PETB during pandemic. This study used the latest data that include COVID-19. In doing so, we provided a systemic and objective overview of research on PETB. Moreover, we aim to showcase bibliometric characteristics and visualize relationships of articles on this topic published in the scholarly reputed journals that are indexed in Web of Science (WoS) between 2000 and 2021.

This paper is organized as follows. First, a review of PETB is provided, and the used materials and methodology are explained. Next, the results of the collaboration network, co-citation network and emerging trends of PETB are presented. Lastly, the discussions, implications, future research directions and limitations are explained.

Pro-environmental travel behaviour (PETB)

Different authors defined PETB in different ways, which are shown in Table 1. Overall, it is regarded as a behaviour embraced by the travellers to protect the environment and to boost economic performance. Not only definitions, different scholars have also studied the notion of PETB based on different theories. For instance, O'Connor and Assaker (2021) considered the norm activation model (NAM) and economic sacrifices theory to study the effect of COVID-19 on PETB. Wang *et al.* (2019) considered the theory of planned behaviour (TPB) and the broken window theory to

examine the moderating effect of environmental background on the relationship between traveller's environmentally responsible behaviour and intention. On the other hand, Kiatkawsin and Han (2017) used value–belief–norm (VBN) theory and expectancy theory to study young travellers' intention to behave pro-environmentally. Whereas Onwezen *et al.* (2013) used NAM and the TPB to explore the function of anticipated pride and guilt on pro-environmental behaviour.

Past studies also examined the drivers of PETB and found that *psychological factors* (Nilsson and Küller, 2000) and *situational factors* (Heydari *et al.*, 2021; O'Connor and Assaker, 2021) are likely to influence pro-environmental behaviour. Again, Han *et al.* (2018) studied the role of user-generated content on travellers' pro-environmental behaviour in the Chinese context. Their study revealed that the content about pro-environmental knowledge and awareness both significantly encourage pro-environmental behaviour. Wang *et al.* (2019) used the broken window theory to explain the importance of environmental background to travellers' environmentally significant behaviour. Whereas Wu *et al.* (2019) investigated the role of information technology on young adults' mobility

Table 1 The definitions of pro-environmental travel behaviour in past studies

Variable	*Definitions*	*Sources*
Pro-environmental travel behaviour (PETB)	"PETB refers to pro-environmental behavior with respect to traveling less, traveling closer to home, traveling less by plane, choosing a destination, selecting transportation, choosing accommodations, making attractions and activity choices, and making more sustainable choices of tourism products in general." (P. 8)	O'Connor and Assaker (2021)
	Pro-environmental travel behaviour refers to the behaviours for " achieving broader environmental and health objectives such as air pollution reduction, physical activity improvement and climate change mitigation." (P. 2)	Ahmed *et al.* (2020)
	PETB "means voluntarily choosing low-carbon travel, including public transport, non-motorised traffic and walking, based on an attitude of caring about the environment and a willingness to sacrifice some degree of convenience, comfort and time." (P. 467)	Chen *et al.* (2019)
	"Activity-travel behavior of an individual can be found by tracking the travel choices one makes to perform any activity and the environmental impact of personal travel is assessed in terms of the number of out-of-home trips, distance traveled, and the mode choice, such as walking, cycling, car and public transport usage. A more pro-environmental activity travel behavior is for example traveling shorter distances to perform a particular activity by using public transport, cycling/walking instead of taking the car." (P. 110)	Adnan *et al.* (2019)
	"Pro-environmental behavior is perceptive conduct executed by human beings in order to mitigate the damaging impact of human activities on the natural environment." (P. 1873)	Chuang *et al*. (2018)
	The PETB is the efforts that "people make, both before and during their vacation, can play an important part in creating a more sustainable tourism sector. For example, choosing accommodation and transportation with low carbon dioxide (CO_2) emissions, can place pressure on the tourism industry to supply products and services that help to satisfy these demands." (P. 196)	Doran *et al*. (2017)
	Peoples' behavioural consideration towards the environmental impact caused by travelling when make the choice of transport means and frequency of journeys for different destinations	Nilsson and Küller (2000)

behaviour. The result shows that the changes in the usage of the Internet can positively influence pro-environmental intention. Based on these discussions, it is evident that there are more empirical studies to examine the drivers of PETB, and less emphasis is given to have a bibliometric analysis on the phenomenon, which this paper attempts to address.

Undoubtedly, the outbreak of COVID-19 has taken a toll on the overall tourism industry's growth and financial performance worldwide. Since the outbreak of COVID-19, it became a global concern whether the pandemic has affected tourists' PETB too. Urban and Braun Kohlová (2022) conducted a panel study before and during the COVID-19 lockdown, and they found that COVID-19 did not change tourists' pro-environmental behaviour. However, O'Connor and Assaker (2021) found that tourists' risk perception of COVID-19 has a positive effect on PETB. COVID-19 has brought a serious threat to the health, environment and socio-economic aspects, and the news about COVID-19 can be seen everywhere. Nevertheless, the studies focusing on the effect of emergencies and crises on PETB are scant (Lucarelli *et al.*, 2020). For instance, the role of risk communication, risk perception of COVID-19 and PETB are still not explored fully. The COVID-19 is still ongoing, but people started to cope with the situation. In this review, we have incorporated studies before and during the pandemic to provide a wider understanding of the matter.

Materials and methodology

Data sources

For bibliometric analysis, it is necessary to obtain high-quality literature as the data source; thus, a reputable database should be selected (Fang *et al.*, 2018). WoS includes the Science Citation Index Expanded, the Social Sciences Citation Index and the Arts and Humanities Citation Index database, which is regarded as an ideal data source for bibliometric analysis (van Leeuwen, 2006; Fang *et al.*, 2018), which contains 12,000 leading journals worldwide. It has been widely used in the bibliometric analysis by many scholars from different disciplines (Fang *et al.*, 2018; Li *et al.*, 2017). As such, we collected data from the WoS Core Collection. In this study, we focused predominantly on environmental aspect and thus used "pro-environmental travel behaviour" as the keyword to search relevant articles. All literature studies that contained the word "pro-environment" either in the abstracts or keywords were included for analysis. To the best of our knowledge, the first article about PETB was published in 2000. Thus, in this study, we considered sources that were published between 2000 and 2021. In order to get high-quality research papers, review articles, book chapters and editorial materials were excluded, which yielded 187 articles to proceed for further analysis.

Knowledge mapping

Knowledge mapping is a kind of bibliometric analysis, which is regarded as "the quantitative analysis of publications in a given field" (Cui *et al.*, 2018, p. 842). It helps scholars to better understand the current research status by providing a systematic and comprehensive knowledge of a specific research field. In bibliometric analysis, the analysis of the keywords enables the researchers to understand the latest hot research topics and the directions of future research. The information of authors, journals, institutions and countries can help scholars to understand the most contributing scholars, most authoritative institution, in order to create academic communication for future collaboration. Co-citation is the most significant analysis in bibliometric analysis because it can show the relations between articles. If an article shows high citation frequency and many links with other articles, it indicates high relevancy and importance of the topic on that particular field (Small, 2003).

In this study, we used CiteSpce5.8.R2 software which was developed by Chaomei Chen. Compared with an earlier visualization tool, it can provide clearer and interpretable results (Chen, 2006). This software has been used by many scholars from different disciplines, such as hospitality research, social commerce research, tourism and so on (Cui *et al.*, 2018; Fang *et al.*, 2018; Li *et al.*,

2017; Mensah *et al.*, 2021; Wei *et al.*, 2015). In the graph of CiteSpace, analytic objectives are represented by nodes (generally a circle shape). The bigger the node, the more valuable it is. And the coloured links between different nodes present their relationship, where different colours represent different publication years.

We analysed the collaboration network, co-citation network and emerging trends using the CiteSpace. The analysis of collaboration network is an image, which can show the frequency of academic collaboration (scholar, country and institution). It is a basic output of bibliometric analysis, which can be conducted by CiteSpace. Co-citation network is another output which represents the most important work in the field because the more important an article is, the higher the number of citations. In the analysis of co-citation, different thicknesses represent different frequencies of co-citation (Chen *et al.*, 2012). Additionally, the emerging trends can be shown by analysis of keywords.

Results

Research outputs and their categories

As depicted in Figure 1, it is a progression of papers published about PETB for 21 years (from 2000–2021). The first article about PETB was published in 2000, and the growth of publication number was seemed to be slow in the next ten years. However, the number of publications had a steady increase from 2011, and there has been a phenomenal growth of the number of publications on PETB from 2017. The number of publications is projected to increase continuously in the future. The growing number of publications shows that PETB is of increasing interest of scholars.

All articles covered 53 subject categories in the WoS. The top ten subject categories are showed in Figure 2, including "hospitality leisure sport tourism" (75 articles; account for 35.4%), "environmental study" (55; 25.9%), "green sustainable science technology" (51; 24.1%), "transportation" (44; 20.8%), "environmental sciences" (37; 17.5%), "transportation science technology" (27; 12.7%), "management" (16; 7.5%), "psychology multidisciplinary" (14; 6.6%), "engineering environmental" (12; 5.7%) and "economics" (11; 5.2%). The top ten subjects' distribution shows PETB is an interdisciplinary research topic. The hospitality, tourism, green sustainability, transportation and environmental issues are the most prominent topics focused by the scholars in this field. From "psychology and behaviour of tourists' to "tourism management related to green sustainability" are all belong to such research areas.

Figure 1 The number of published papers on pro-environmental travel behaviour between 2000 and 2021

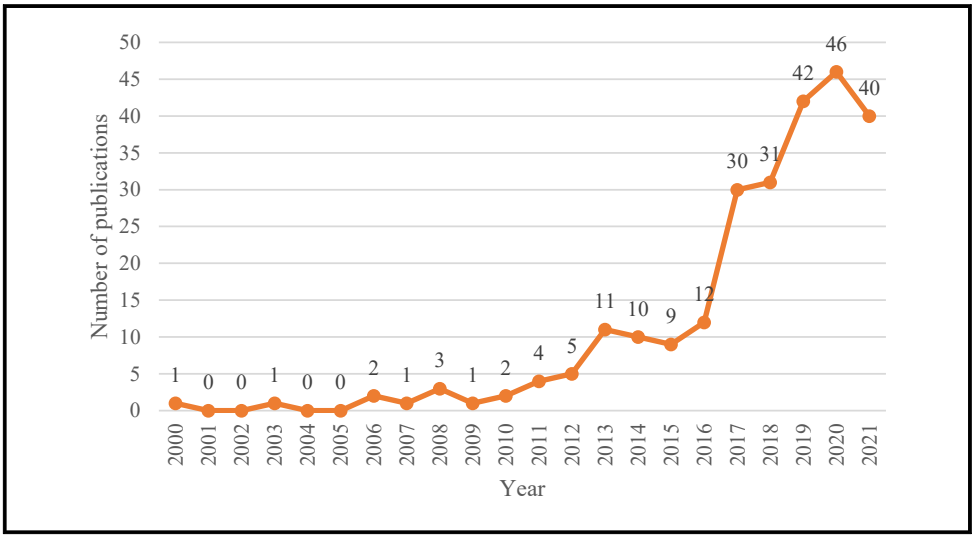
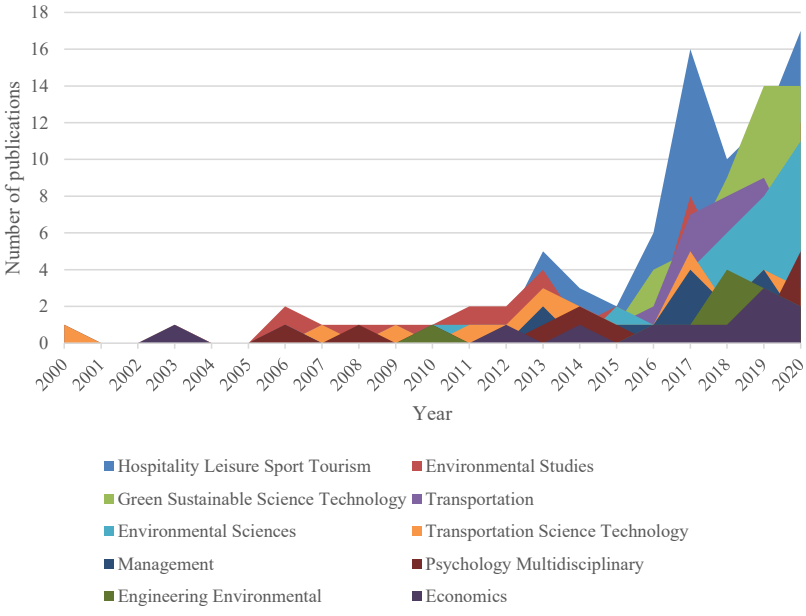


Figure 2 Annual article output in the ten subject categories



The collaboration network of pro-environmental travel behaviour

Country collaboration network. The country collaboration network consists of 47 countries and 85 links between 2000 and 2021, which is showed in Figure 3. Based on the close links, different countries have established relatively a more matured collaboration network. The coloured lines indicate that Germany, Norway, Netherlands and Belgium have had a close collaboration in recent years. England, the USA, China, Australia and Canada accounted for half of the publications. The top ten countries based on frequency are shown in Table 2. England has the largest contribution with 40 articles and the highest centrality (0.76), and the USA is the second contributor with 28 articles. It is worth noting that China is the third contributor with 21 articles, which reflects the rapid development in tourism and the sustainable tourism development policy of China (Xu and Sofield, 2016). The tourism industry plays a significant role in mobilizing economic growth in China (Xu and Sofield, 2016). Additionally, Australia and New Zealand are referred as at-risk tourism destinations because of the climate change (Fang *et al.*, 2018), which motivated many researchers to investigate this field.

Institution collaboration network. There are 213 nodes and 174 lines in the institution collaboration network between 2000 and 2021, which is shown in Figure 4. It is worth noting that the collaboration between institutions is relatively loose. The research institutions have formed a cooperative network dominated by small groups, but not a large and close cooperative network. Therefore, it can be viewed as the research community is not mature yet. However, based on the colour of the links, the Hasselt University and Katholieke University have a close collaboration network in recent years.

Top ten institutions with the highest number of publications are showed in Table 3. The Sejong University of South Korea has the highest number of publications (i.e. nine articles), and the University of Surrey, which is located in England, has the second highest publications (i.e. six articles). The Hasselt University of England and Dong A University which are based in South Korea both have published five articles, respectively. On the other hand, Norwegian University Science and Technology, Tianjin University, Griffith University and Lunds University published four articles, respectively. The University of Queensland and University Exeter published three articles each.

Figure 3 Country collaboration network

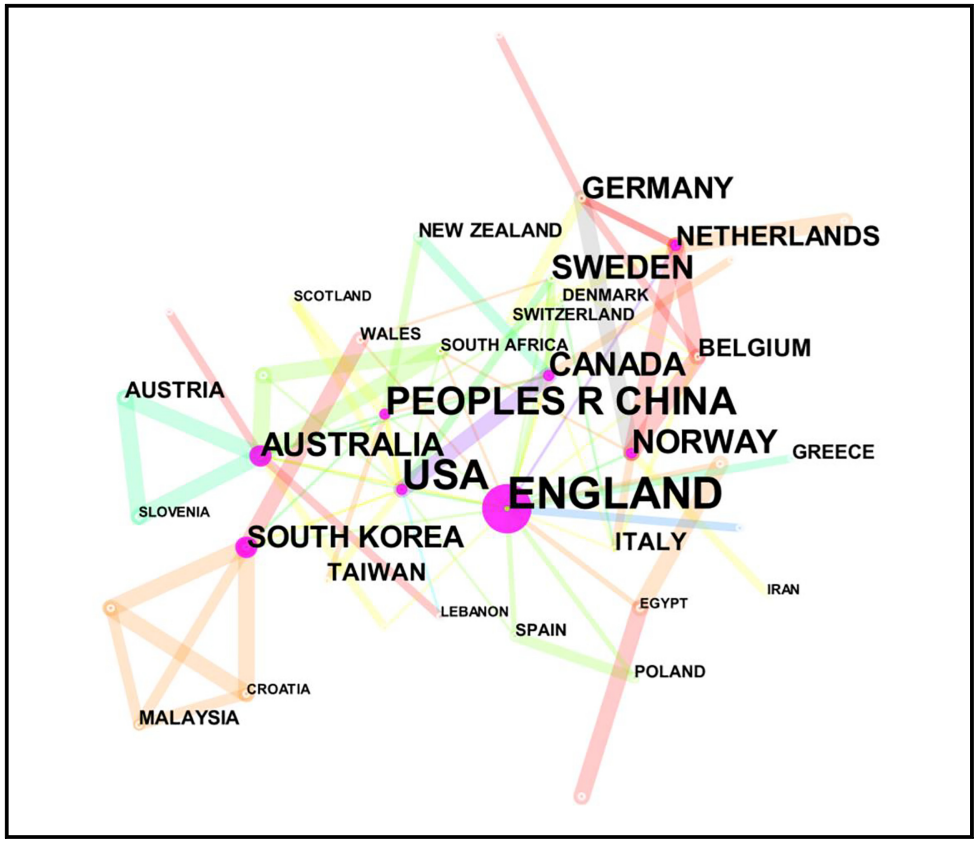


Table 2 Top ten countries based on frequency

Country	*Frequency*	*Centrality*
England	40	0.76
USA	28	0.18
China	21	0.12
Australia	15	0.25
Canada	14	0.13
Norway	14	0.12
Sweden	13	0.01
South Korea	11	0.21
Germany	10	0.08
Netherlands	8	0.16

Note(s): Centrality: a metric of a node measures how likely an arbitrary shortest path in a network will go through the node, which shows the contribution of a node to make connections with other nodes in a network

Author collaboration network. There are 269 authors and 255 collaboration links found for PETB research that are published between 2000 and 2021, which is presented in Figure 5. However, the collaboration network seems fragmented, and only few authors exhibit having a close collaboration. Name of the top ten authors based on the number of publications are showed in Table 4. Heesup Han from Sejong University has the most contribution in this field with eight published articles followed by Alexander Yuriev from Concordia University and Arora Arnadottir from the University of Iceland who has published three articles in this field, respectively. Rest of the

Figure 4 Institution collaboration network

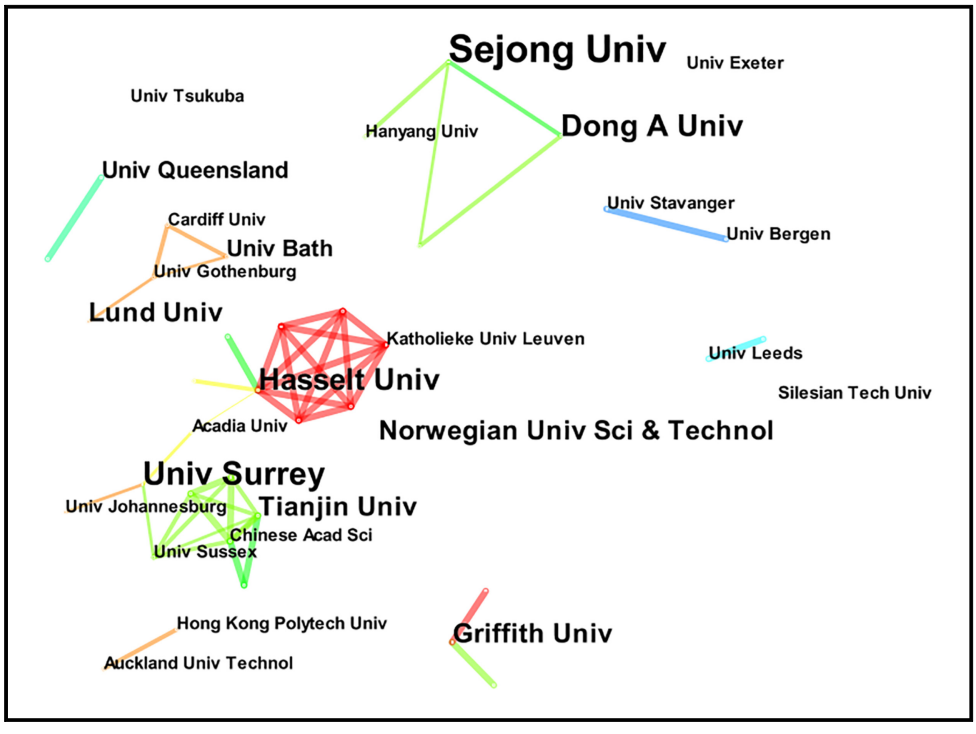


Table 3 Top ten institutions based on frequency

Institution	*Country*	*Frequency*
Sejong University	South Korea	9
University of Surrey	England	6
Hasselt University	Belgium	5
Dong A University	South Korea	5
Norwegian University Science and Technology	Norway	4
Tianjin University	China	4
Griffith University	Australia	4
Lunds University	Sweden	4
The University of Queensland	Australia	3
University Exeter	England	3

authors in this top ten list published two articles each whereas others published only one article, respectively. Since PETB is an emerging research topic, most scholars are relatively new in this field and many of them are currently doing research on this topic.

The co-citation network of pro-environmental travel behaviour

Document co-citation network. In regard to the document co-citation network, there are 476 references and 1,431 co-citation links found between 2000 and 2021, which are shown in Figure 6. Indexing terms and log-likelihood ratio (LLR) were used to label the clusters. LLR is one of the algorithms, which is used to extract cluster labels at different locations in the cited literature (Fang *et al.*, 2018), which is widely used and recommended. In the document co-citation network, the silhouette score is all above 0.8, which indicates that the clusters have reliable quality. The top 20

Figure 5 Author collaboration network

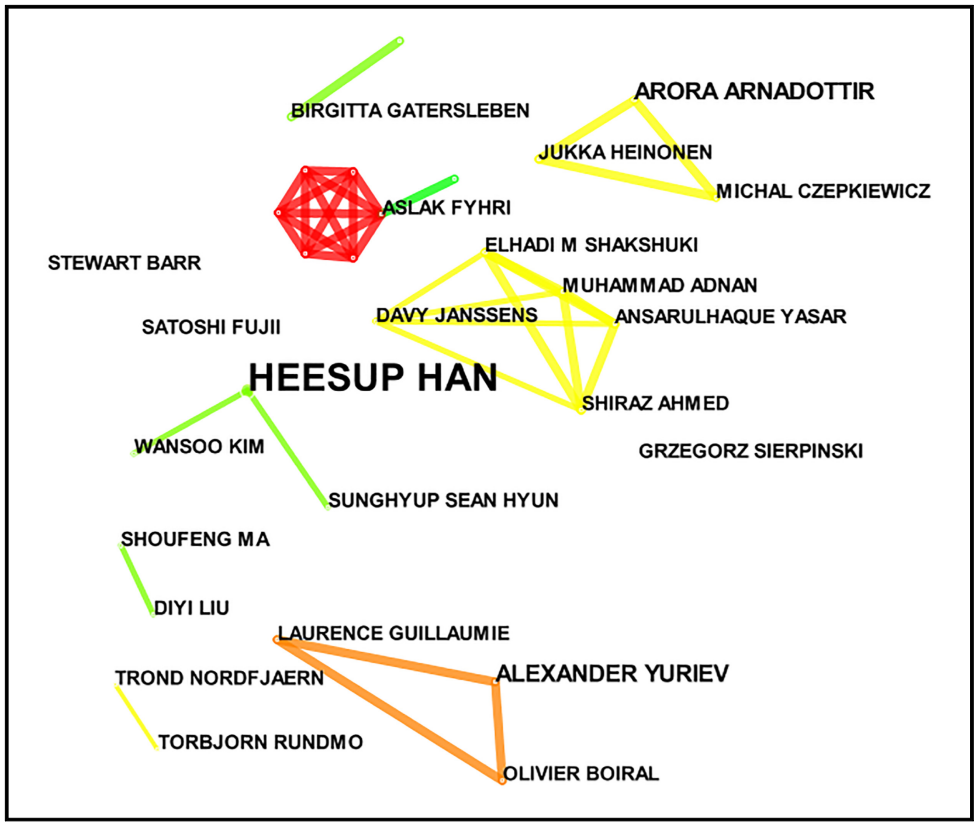


Table 4 Top ten authors based on frequency of publications

Author	*Frequency*	*Institution*
Heesup Han	8	Sejong University
Alexander Yuriev	3	Concordia University
Arora Arnadottir	3	University of Iceland
Satoshi Fujll	2	Kyoto University
Elhadi M Shakshuki	2	Acadia University
Shoufeng Ma	2	Tianjin University
Sunghyup Sean Hyun	2	Hanyang University
Torbjorn Rundmo	2	Norwegian University of Science and Technology
Shiraz Ahmed	2	Hasselt University
Jukka Heinonen	2	University of Iceland

clusters are shown in Table 5. Pro-environmental norm is the largest cluster with 57 member references, followed by towel reuse, sustainable lifestyles, pro-environmental attitudes, biospheric values and so on.

In respect to the mean cite year, most of the clusters are new clusters in recent years, in which #14 pro-environmental behavioural intentions were found to be the latest cluster (mean cite year is 2017), which indicates to be the research hotspot. Liu *et al.* (2017) studied the low-carbon travel intention of residents of Tianjin and found that the low-carbon travel policy and low-carbon awareness can moderate low-carbon travel intention between TPB variables and VBN variables. Hu *et al.* (2019) studied tourists' intention to take part in the activity named "zero litter initiative" in Huangshan National Park, which is located in China to protect its scenic environment. Their study

Figure 6 Document co-citation network

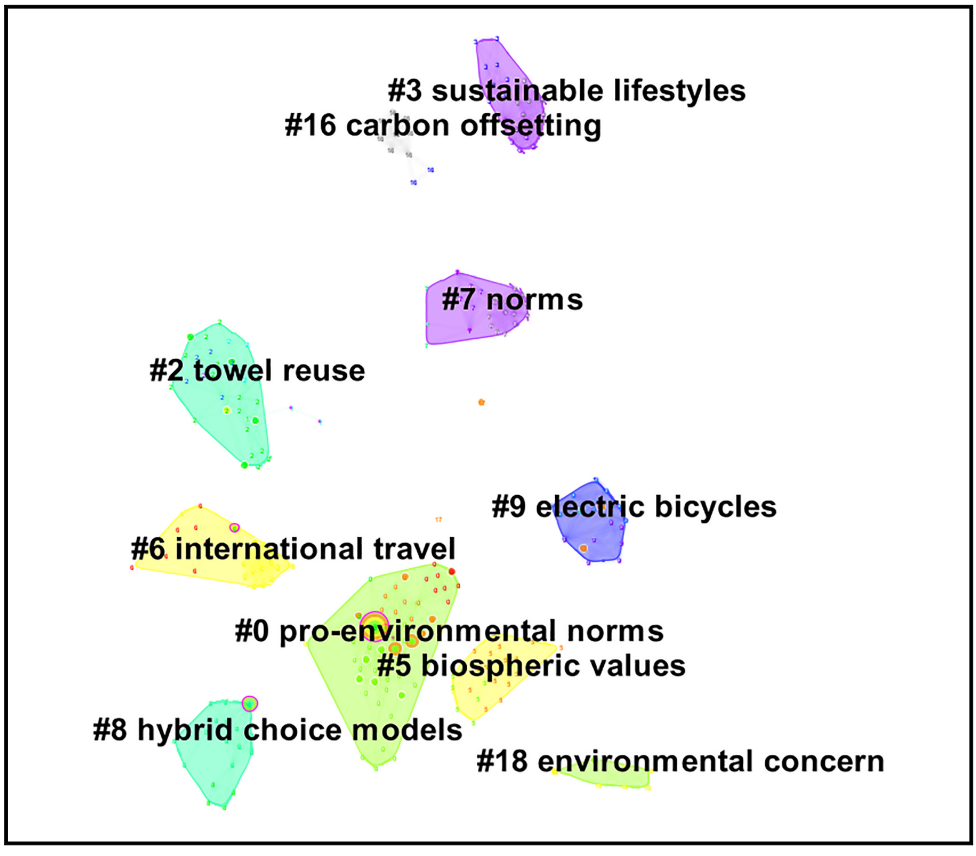


Table 5 Summary of top 20 clusters

Cluster ID	*Size*	*Silhouette score*	*Label (LLR)*	*Mean (cite year)*
0	57	0.829	Pro-environmental norms	2016
1	34	0.979	Interpretation	2012
2	29	0.956	Towel reuse	2012
3	26	0.954	Sustainable lifestyles	2008
4	26	1	Pro-environmental attitudes	1996
5	24	0.937	Biospheric values	2016
6	24	0.989	International travel	2008
7	22	0.971	Norms	2013
8	18	0.994	Hybrid choice models	2010
9	16	0.966	Electric bicycles	2003
10	16	1	Greenhouse gases	2009
11	16	1	Theory of planned behaviour	2004
12	15	1	Demographic characteristics	2001
13	12	1	Psychological	2004
14	11	1	Pro-environmental behavioural intentions	2017
15	11	0.989	Choice architecture	2015
16	10	0.964	Carbon offsetting	2012
17	9	0.958	Downshifting	2006
18	7	1	Environmental concern	2015
19	6	1	Destination images	2012

found that lower ticket prices can increase the willingness of tourists to take part in the initiative. Likewise, Kiatkawsin and Han (2017) studied young travellers' intention to behave pro-environmentally. They combined VBN theory and the expectancy theory to conceptualize their research framework. The result showed that their model has better predictive power, and the expectancy theory positively influences pro-environmental personal norms. In another study, Wu *et al.* (2021) divided pro-environmental travel intention into two: low-effort and high-effort. They considered social influence as a moderator variable between moral obligation and pro-environmental behaviour. Based on the output provided in Table 5, #4 pro-environmental attitude is a saturated and comparatively old phenomenon.

The most used theory in studying PETB is found to be TPB (#11), which has the highest frequency of use in analysing tourists' behaviour (Adnan *et al.*, 2019; Bae and Chang, 2021; Esfandiar *et al.*, 2020; Hu *et al.*, 2019; Liu *et al.*, 2017, 2020).

The most cited articles are often considered milestone research due to their seminal contributions (Chen, 2006). Top ten most-cited papers are shown in Table 6; all of them are cited more than six times. Han's (2015) paper has the highest citations (19 times cited). As mentioned before, Han also has the most publications on PETB. In this article, he focused on the green lodging context. He developed a comprehensive framework to investigate tourists' pro-environmental intentions in the green lodging context using VBN theory and the TPB. The results showed that awareness of consequences and the normative process have an important role in generating intention, and non-green alternatives' attractiveness posed a strong moderating effect. Chen and Tung's (2014) research is second highly cited paper. They confirmed that environmental concern can influence visitors' perceived moral obligation, attitude, subjective norms and perceived behaviour control, which in turn influences the intention of visiting the green hotels. On the other hand, Klöckner's (2013) paper is the third highly cited research, who developed a model to understand individuals' psychology of environmental behaviour using meta-analysis.

Author co-citation network. There are 477 authors and 2,379 collaboration links in the author co-citation network, which is shown in Figure 7. There is a close co-citation relationship between scholars. It should be noted that only the first author in an article is considered in this analysis.

Top ten most-cited scholars are shown in Table 7. The scholars who developed theory had a high co-citation frequency. For instance, Ajzen is the most-cited author with 98 citations and also has the most centrality (0.42) that is referred as to the metric of the transformative potential of a scientific contribution. He is a Professor in Psychology at the University of Massachusetts Amherst. His work on the TPB has a huge influence in the PETB field and has obtained impressive number of citations. This result is in accordance with the analysis of document co-citation network that the TPB is the most commonly used theory by the scholars in PETB research. Bamberg, a Professor of Social Psychology from the University of Applied Science Bielefeld, analysed psycho-social determinants of pro-environmental behaviour which is found to be the second highly cited author. Han's name

Table 6 Top ten most-cited papers with co-citation network

Citation counts	*References*	*Cluster*
19	Han (2015)	0
9	Chen and Tung (2014)	0
8	Klöckner (2013)	8
8	Alcock *et al.* (2017)	6
8	Onwezen *et al.* (2013)	0
8	Kiatkawsin and Han (2017)	0
7	Lind *et al.* (2015)	0
6	Blok *et al.* (2015)	5
6	Fornara *et al.* (2016)	0
6	Truelove *et al.* (2014)	1

Figure 7 Author co-citation network

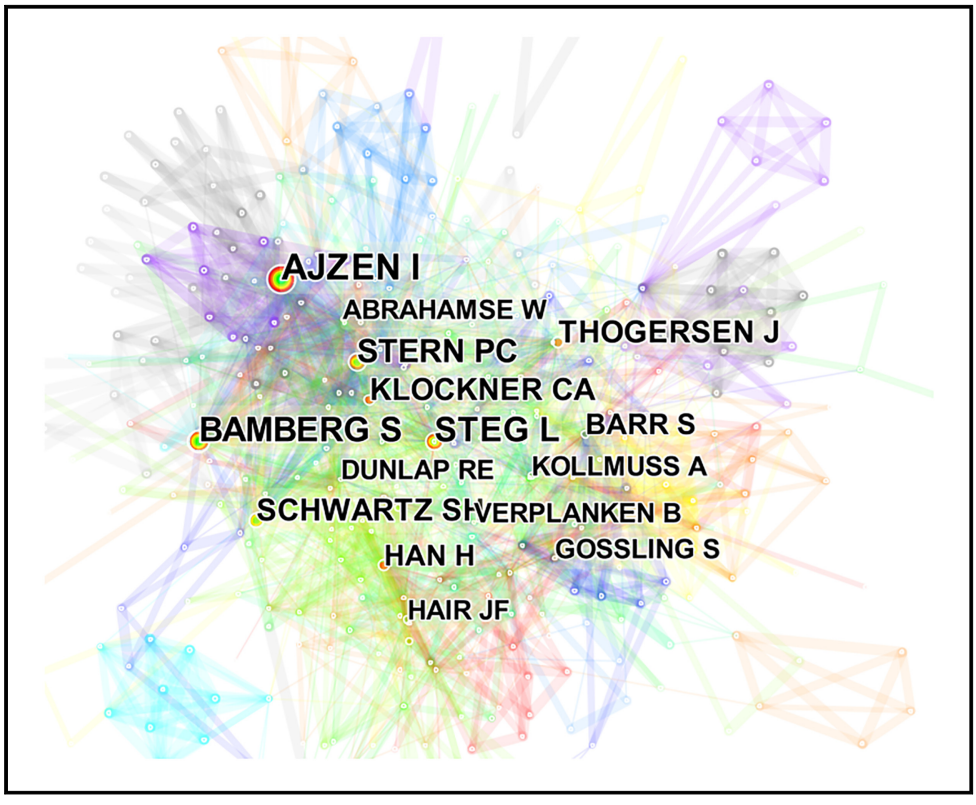


Table 7 Top ten most-cited authors with co-citation frequency

Authors	*Frequency*	*Centrality*
Icek Ajzen	98	0.42
Sebastian Bamberg	81	0.11
Linda Steg	77	0.10
Paul C. Stern	69	0.09
Shalom H. Schwartz	53	0.04
Christian Klockner	47	0.04
John Thogersen	44	0.07
Heesup Han	38	0.13
Stewart Barr	34	0.16

and his publications appear in both Table 6 (most cited papers) and Table 4 (top ten authors), which further confirms his contribution to PETB research.

Journal co-citation network. Journal co-citation network represents the set of journals that contribute to a specific research area. In regard to the PETB, the most contributing journals over the period of last 21 years are shown in Figure 8. A total of 452 journals were found, and the top ten most-cited journals are shown in Table 8. The co-citation frequencies of the top ten journals are more than 70. The *Journal of Environmental Psychology* is the most contributing journal with 141 co-citations, followed by *Environment and Behaviour* with 123 co-citation frequencies. The majority of the journals focus on tourism, environment and psychology.

Table 9 shows the most prolific journals in PETB research. *Journal of Sustainable Tourism* is the leading journal in this field with 26 articles published between 2000 and 2021. The second most

Figure 8 Journal co-citation network

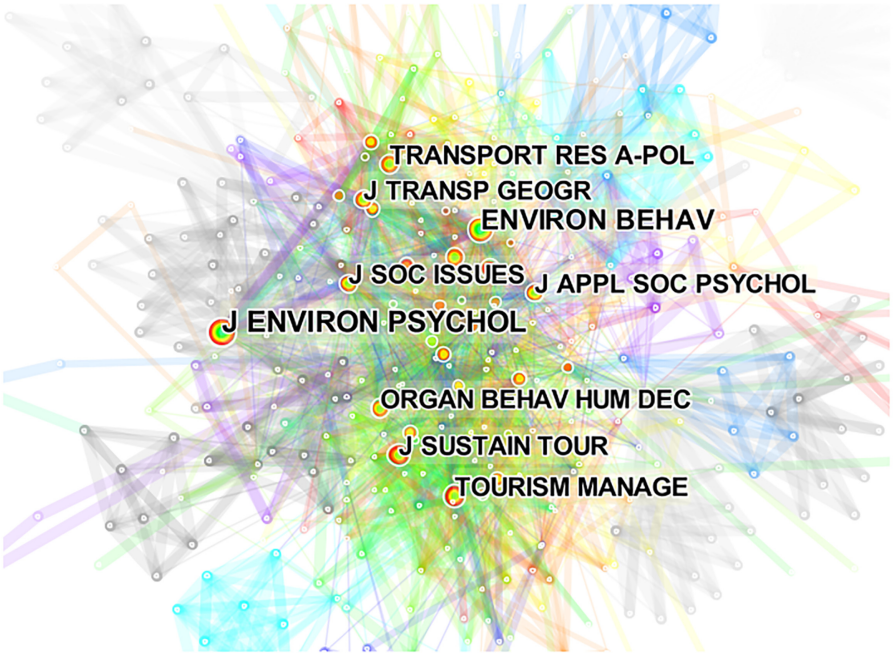


Table 8 Top ten most-cited journals with co-citation frequency

Journal name	*Frequency*	*Centrality*	*Impact factor*
Journal of Environmental Psychology	141	0.03	5.192
Environment and Behaviour	123	0.13	6.222
Journal of Social issues	83	0.05	3.424
Organization Behavior and Human Decision Processes	80	0.03	4.941
Journal of Applied Social Psychology	76	0.05	2.122
Journal of sustainable tourism	74	0.01	7.968
Transportation Research Part A-Policy and Practice	71	0.02	5.594
Tourism Management	70	0.05	10.967
Journal of Transport Geography	70	0.06	4.986

Table 9 Top ten most prolific journals

Journal	*Publication number*	*Impact factor*
Journal of Sustainable Tourism	26	7.968
Sustainability	15	3.251
Tourism Management	9	10.967
Transportation Research Part D Transport and Environment	8	5.495
Journal of Cleaner Production	7	9.297
Frontiers In Psychology	6	2.99
Transportation	6	5.192
Transportation Research Part F Traffic Psychology and Behavior	6	3.261
Transportation Research Part A Policy and Practice	5	5.594

prolific journal is *Sustainability* (15), followed by *Tourism Management* (9), *Transportation Research Part D Transport and Environment* (8) and *Journal of Cleaner Production* (7). It should be noted that, Table 8 shows the high frequency of citations of the contributing journals to the PETB filed,

whereas Table 9 highlights the journals with high impact factors that published papers related to PETB. It is commonly believed that the journals with high impact factors may have higher citation frequencies (Fang *et al.*, 2018).

Emerging trends of pro-environmental travel behaviour

References with highest number of citations. When an article receives a rapid citation in a short term, it forms a citation burst, which can partly show the research dynamics in a specific field (Fang *et al.*, 2018). Although PETB is an emerging topic, some articles received very high number of citations as shown in Table 10. Based on the output showed in this table, the first wave of the citation burst started between 2011 and 2012, and the second wave of the citation burst appeared between 2015 and 2018, which is in accordance with the publication curve that is discussed in the previous section. The first citation burst is research about exploring the changing nature of sustainable lifestyles, the relationship between home-based environmental practices and tourism-based environmental practices by Barr *et al.* (2010).

Keywords analysis. The analysis of keywords can reflect the development trends of the topic. It also assists to understand the future research directions by highlighting the research hotspots, i.e. highly prioritized topics in the field. The time zone of PETB is shown in Figure 9, and the top ten keywords are shown in Table 11 based on the frequency. Keywords with the same meaning were merged and those with no meaning were eliminated.

It is found that pro-environmental behaviour is the most common keyword with 112 frequencies, which appeared as a keyword in 2006. Although some scholars attempted to study PETB, it was not a keyword used by scholars before 2006. The keyword PETB was followed by attitude (48), planned behaviour (44), climate change (28), intention (27), habit (21) and the like. The keywords related to the behaviour of travellers have high frequencies. The keyword planned behaviour belongs to the TPB, which is the most commonly used theory by scholars in this field, which is in

Table 10 Top ten references with the highest number of citations

References	Strength	Begin	End	2000-2021
Barr *et al.* (2010)	2.66	2011	2014	
Shove (2010)	2.26	2012	2014	
Abrahamse *et al.* (2009)	2.26	2012	2014	
Ramkissoon *et al.* (2013)	2.05	2015	2017	
Miao and Wei (2013)	2.05	2015	2017	
Klöckner (2013)	3.13	2016	2018	
Onwezen *et al.* (2013)	3.51	2017	2018	
Han (2015)	2.84	2017	2021	
Chen and Tung (2014)	3.76	2018	2019	
Donald *et al.* (2014)	2.07	2018	2019	

Figure 9 Time zone view of keywords

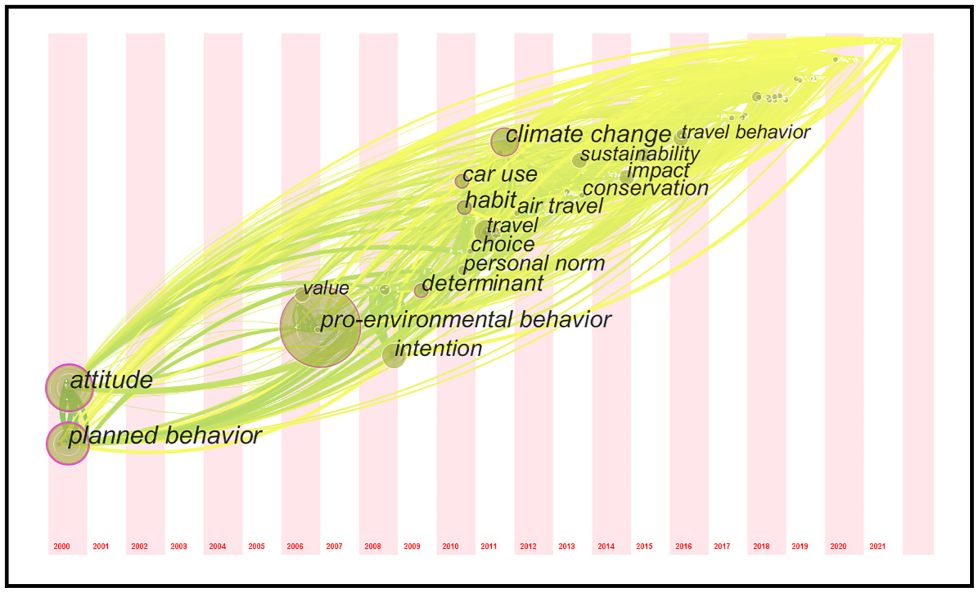


Table 11 Top ten keywords based on frequencies

Keyword	*Frequency*	*Centrality*
Pro-environmental behaviour	112	0.14
Attitude	48	0.28
Planned behaviour	44	0.32
Climate change	28	0.2
Intention	27	0.06
Habit	21	0.15
Travel	19	0.02
Impact	17	0.08
Value	17	0.11
Determinant	17	0.09

accordance with the analysis of the previous section. Since the keywords "attitude" and "intention" are part of the TPB, they also exhibit high frequencies.

Not surprisingly, climate change is highly related to PETB. The negative effect of the tourism activities on climate change has been subject to many studies (Ahmed *et al.*, 2020; Fang *et al.*, 2018; Hares *et al.*, 2010). It is suggested that 5% of global carbon dioxide emissions are produced by tourism activities, in which transport sector contributes more than 90% of carbon emission (Gössling, 2002). It clearly indicates that, travellers' pro-environmental behaviours are greatly related to climate change. The choice of transportation and frequencies of travel can directly influence greenhouse gas emissions. In 2007, climate change was regarded as the most serious threat to the sustainability of tourism in the *Second International Conference on Climate Change and Tourism* (Fang *et al.*, 2018). Since then, researchers started to put significant efforts in addressing the issue related to PETB.

Based on the keywords analysis, car use, air travel and the use of transportation are found as some of the topics in PETB research. Perhaps this is due to the fact that transportation is the major source of air pollution. Klöckner and Blöbaum (2010) built an action determination model to further study ecological behaviour using the example of travel mode choice. Car choice habit was chosen as the habitual processes in their study, and the results showed that habit mediates the link between social influence and personal norm; it also moderates the relationship between intention

and behaviour. Geng *et al.* (2017) studied the types of motivations on urban residents' travel mode. The results showed that pro-environmental motivation significantly promote the choice of green travel mode choice, such as bicycling, walking and public transportation. Kaida and Kaida (2015) confirmed the existence of the spillover effect of congestion charging on pro-environmental behaviour for people who shifted travel mode from car to more pro-environmental mode.

It should be noted that some new keywords can easily be overlooked since those keywords are relatively new and appear less frequently. Therefore, Table 12 shows the new keywords which appeared repeatedly in the past two years, which can further present the research hotspots in PETB research.

"COVID-19" is a new keyword that appeared in 2021 because of the outbreak of COVID-19. The "tourism and leisure" industry is one of the most threatened global industries, which is affected by the pandemic (Abbas *et al.*, 2021). COVID-19 did not only affect the economy but also affected tourists' behaviour and mental health (Abbas *et al.*, 2021; Bauer *et al.*, 2021). With the ongoing pandemic, more scholars started to investigate the effects of COVID-19 on PETB. For instance, O'Connor and Assaker (2021) refined and expanded the COVID-19 risk perception measure, which combined norm activation, economic sacrifices and risk perception theories. The results showed that the risk perception of COVID-19 indirectly influences pro-environmental behaviour through environmental concern, environmental responsibility and environmental moral obligation. Willingness to make economic sacrifices for the environment is found to be a new variable which directly influences PETB. It also acts as a mediator between risk perception of COVID-19 and PETB. However, this study did not investigate the mechanism of how the COVID-19 risk perception can be formed and did not consider the external factors that may influence PETBs. Chi *et al.* (2021) studied the festival travellers' intention for practicing sanitation activities and keeping social distance during COVID-19 in the Chinese context. Their study revealed that problem awareness of COVID-19 can positively influence the ascription of responsibility indirectly and eventually evoke the sense of obligation to consider pro-social behaviours. The sense of obligation is likely to influence the intention to practice sanitation activities. Although some scholars have studied the effect of COVID-19 on pro-environmental behaviour, there are many aspects yet to unveil. More variables should be considered, and different underpinning theories should be regarded to understand the issue better.

Besides, the value orientation, negative spillover, carbon footprints affect, biospheric and adolescent are all new keywords in recent years. These keywords probably can be regarded as the future research hotspots in PETB field.

Discussion and future research directions

In this study, the CiteSpace analysis outputs provide the bibliographic records on PETB research. It presents a unique and interesting picture of the PETB knowledge domain. The analysis suggests that PETB is an emerging research topic. Nevertheless, there is an increasing trend among researchers investigating this issue, and the number of publications has increased rapidly in recent years. Different countries have close collaboration in PETB. England has the largest contribution with 40 published articles, and the USA is the second contributor with 28 articles. Likewise, China, Australia, Canada, Norway, Sweden, South Korea and Germany all have contributed to this field.

Table 12 Repeated keywords in the past two years

Keywords	*Frequency*	*Year*
Covid-19	2	2021
Value orientation	2	2020
Negative spillover	2	2020
Carbon footprint affect	2	2020
Biospheric	2	2020
Adolescent	2	2020

Nevertheless, the collaboration network of authors and institutions both have a loose structure, and most notes are not connected, which indicates that only a part of the authors and institutions have a close collaboration. It means that the academic collaboration between scholars and institutions is not matured on this topic. As such, in the future, more academic conferences or international academic exchanges on PETB can be organized to enhance the collaboration among researchers and institutions. The analysis suggests that Heesup Han from Sejong University has the most contribution in this field with eight published articles. Alexander Yuriev from Concordia University and Arora Arnadottir from the University of Iceland published three articles, respectively, in this field. It is worth noticing that Hasselt University and Katholieke University have had a close collaboration network in recent years.

In the analysis of the document co-citation network, #0 Pro-environmental norms is found to be the largest cluster with 57 member references, followed by towel reuse, sustainable lifestyles, pro-environmental attitudes, biospheric values and so on. In the analysis of author co-citation, Ajzen who developed the TPB has received the highest number of citations. And the TPB is the most common theory used by scholars in PETB research. Based on the journal co-citation analysis, *Journal of Environmental Psychology* and *Environmental and behaviour* are the leading journals in this field. Basically, the majority of the journals are based in tourism, environment, and psychology.

Future researchers who are interested to work on PETB in the future may look at the analysis of citation burst and keywords. It is found that pro-environmental behaviour is the most common keyword with 112 frequencies, followed by attitude (48), planned behaviour (44), climate change (28), intention (27) and habit (21), which can be considered as the research hotspots in this field. Psychological variables such as planned behaviour, intention and habit all have huge research potential. Due to the global concerns on natural calamity and environmental pollution, "environmental problem" is a great research area at present and also in the future. Climate change is another hotspot since PETB can contribute to reduce the greenhouse gas emissions. Moreover, COVID-19 is a new keyword that came up in 2021 due to the outbreak of COVID-19. With the ongoing pandemic, more scholars started to study the effects of COVID-19 on PETB. Besides, some new keywords are probably the future research spots in PETB field, such as value orientation, biospheric value orientation, negative spillover, carbon footprints affect (Whitmarsh *et al.*, 2020) and adolescent (Balundė *et al.*, 2020).

Whitmarsh *et al.* (2020) studied climate scientists' carbon footprints, which can be replicated to examine other individuals' carbon footprints such as bankers, educators, travellers, etc. Balundė *et al.* (2020) studied the relationship between adolescents' environmental concern and their pro-environmental behaviour. Studies to understand adolescents' pro-environmental behaviour are scant, although children also take part in the tourism activities and play significant role to mitigate climate change. Therefore, understanding adolescents' pro-environmental behaviour can be a good future research direction.

Conclusion, implications and limitations

Using CiteSpace, this study provides a holistic and comprehensive knowledge mapping in PETB for academics. This study not only helps scholars to understand the definition of PETB, collaboration network, co-citation network and emerging trends but also visually displays the knowledge for the interested researchers. It will help scholars to see the research status of the past and will enable them to have a general understanding of the future research trend. The results also suggest that researchers need to improve their collaboration with each other, especially in transnational and interdisciplinary research.

Furthermore, this study can help interested scholars to improve their research efficiency and save research time. The most contributing scholars and institutions are highlighted in this study, which can help scholars find the proper partners to conduct future studies in the field. The most cited journals can serve as the suitable literature source and publication platforms for the scholars.

Moreover, this study illustrates that PETB is a potential research area for scholars. Psychological variables and environment problem are currently the focus of scholars, which have great value in

the future, such as attitude, planned behaviour, climate change, intention and habit. This study also suggests potential research directions to combine research topics such as COVID-19, value orientation, negative spillover, carbon footprints affect, biospheric value and adolescents, all of which are found to be the latest keywords in the present literature.

This study considered only "pro-environmental travel behaviour" as the search keyword. Future studies can expand the research scope by adding more keyword, such as sustainable travel behaviour. It should be noted that the logic of research cannot be fully analysed by bibliometric software such as the relationship between variables. Therefore, a systematic literature review or meta-analysis should be carried out to summarize the existing literature in the field. Lastly, different paradigms, metrics and methods are suggested to be used to explore and explain the notion of PETB by future scholars.

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