



# What Can We Glean from the Past Seven Decades of Voluntary Carbon Emissions Disclosure Research?

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## ABSTRACT

This paper provides a comprehensive analysis of global research on carbon emission disclosure, highlighting the challenges associated with climate change and its impact on businesses. To achieve this, the study analysed a dataset comprising 745 publications that were published between 1953 and 2022, obtained from the Scopus database, using bibliometrics, content analysis, and network approach methods. The results, analysed using VOSviewer, MS Excel, and Harzing's Publish or Perish software, revealed that voluntary carbon emission disclosure (VCED) is a crucial area of study. The analysis identified various themes and highlighted limitations in the literature's growth while offering suggestions for further research. The study employed a combination of bibliometric, content, and network analyses to investigate carbon emission disclosure.

**Keywords:** Bibliometric Analysis, Carbon Emission Disclosure, Climate Change, Content Analysis, Greenhouse Gas Disclosure

**JEL Classifications:** Q56, M14

## 1. INTRODUCTION

Global warming has been a critical issue for the last few decades due to the effect of greenhouse gas (GHG) emissions. Carbon dioxide (CO<sub>2</sub>) makes up the vast majority of GHG, accounting for 68% of the total GHG globally, and has been considered the most significant contributor to global climate change (Gür, 2022). As CO<sub>2</sub> concentrations in the atmosphere are rising at an alarming rate, it systematically commits the planet to dangerous future rise in global warming. It has been reported that global CO<sub>2</sub> emissions were stable between 2014 and 2016, increasing by 1.6% in 2017 and 2.7% in 2018, while reaching its highest-ever level in 2019 (Carrington, 2021). The world-wide escalation of the Coronavirus 2019 (COVID-19) pandemic saw the largest decline in heat-trapping emissions in 2020, resulting in its lowest level since 2006. Compared to 2019, global carbon emissions decreased 8.8% in the first half of 2020 (Liu et al., 2020). Nonetheless, these substantial drops in emissions were only transient as governments

worldwide began to bolster their economic recovery (Nguyen, 2021). Hence, due to the increase in global emissions to pre-pandemic levels and the potential for irreversible consequences (Nguyen, 2021), the climate challenge seems more dire and urgent than ever (Newburger, 2020).

Ongoing CO<sub>2</sub> emissions emitted into the atmosphere pose a serious question mark on attaining the sustainable development goals (SDG) by 2030. The SDG 13 seeks to have governments, organizations, and the general population take immediate action to combat global warming and its effects, in addition to reducing GHG emissions (McCullough and Murfree, 2022). Thus, if the goal of sustaining the 1.5C (2.7F) global warming limit is to be achieved, emissions must be reduced by 45% this decade. Therefore, there is pressure on national-level authorities and intergovernmental organizations to take initiatives to stop the rising trend in global CO<sub>2</sub> emissions (Nguyen, 2021). Numerous activities across various industries are likely required to meet

these expectations. In a specific academic research context, global researchers also seek to explore carbon reduction and mitigation strategies and emphasise greater attention towards voluntary carbon emission disclosure (VCED).

However, expansion in the VCED research field entails several risks, including the risk of overlooking important research areas because it is almost impossible to cover the whole domain's status quo. Scholars have performed several bibliometric analyses on specific carbon emission issues in the past and obtained useful results. Nevertheless, a comprehensive bibliometric analysis of VCED remains an under-researched area.

This paper aims to comprehensively map and graphically analyse VCED from a bibliometric standpoint. It focuses on key topics, existing VCED research dynamics, and future research potentials. This bibliometric study also aimed to identify the publication patterns and intellectual framework of this field. The research questions (RQs) that are addressed are as follows:

- RQ1: What is the present state of carbon emission disclosure?*  
*RQ2: Which carbon emission disclosure papers are the most important?*  
*RQ3: What are the most popular themes in carbon emission disclosures?*  
*RQ4: Who are the most well-known carbon emission disclosure scholars?*  
*RQ5: How is the collaboration on carbon emission disclosure research now progressing?*  
*RQ6: What conceptual framework drives current carbon emission disclosures?*  
*RQ7: Which aspects of carbon emission disclosure require additional research in the future?*

The remainder of this paper is organised as follows. The first section emphasizes on a literature review on carbon emission disclosure, followed by the methodologies employed in the investigation. The analysis and findings are presented next, followed by the discussion and conclusion of this study.

## 2. LITERATURE REVIEW

The United Nations Framework Convention on Climate Change (UNFCCC) came into force on 21<sup>st</sup> March 1994 to prevent “dangerous” human interference with the climate. Various governments, policymakers, and international organizations have become concerned over accelerating climate change in the last 10 years that has affected economic, financial, and social perspectives. Thus, to stop anthropogenic hazards (caused by human action or inaction) that interfere with the climate system, these authoritative entities plan to maintain GHG levels at or below a certain level. As a result, governments around the world have created and put into place a variety of market- and non-market-based policies to reassure businesses that they ought to cut their carbon footprints (He et al., 2021).

Environmental disclosure has drawn a lot of interest as an important area of research, especially the disclosure of carbon-related information by public organizations mainly due to the

negative consequences of climate change (Bilal et al., 2021; Tuesta et al., 2022). Carbon accounting has emerged in response to the Kyoto Protocol to enable reporting on carbon footprints (Tuesta et al., 2022). The Paris Agreement in 2015 signalled a watershed in global initiatives on global warming and has encouraged carbon information disclosure by firms all over the world (Tuesta et al., 2022). The disclosure of GHG information is not currently required by any specific international accounting standard (Borghesi et al., 2018); however, the Greenhouse Gas Protocol, the Carbon Disclosure Project, and the Global Reporting Initiative (GRI) are the three initiatives that predominate and set the standards for carbon reporting (Tuesta et al., 2022).

Carbon emission disclosures can also be mandated or made voluntarily and at various levels (global, national, or corporate) (Tuesta et al., 2022). However, in the majority of nations, disclosures are optional (UNFCCC, 2021). According to Kalu et al. (2015), VCED is a crucial component in efforts to mitigate climate change and reflects organizational-level activities that are instrumental for reducing carbon footprints (Borghesi et al., 2016). Companies can use VCED to describe how climate change is portrayed and strategically managed (Van Zijl et al., 2017). As part of its environmental commitment, VCED also puts pressure on businesses to submit to environmental norms and standards (Debnath, 2019), disclose information about their emissions, and reduce the emissions (Tuesta et al., 2022). Their commitment to upholding strict moral principles, prioritizing stakeholders, and achieving long-term sustainability performance is signalled by extensive disclosure (Bui et al., 2021).

The VCED must be able to ensure that readers receive a precise and comprehensive explanation of the firm's carbon footprint and the impact of its operations in order to be effective (Talbot and Boiral, 2015). Financial reports are also more accurate and reliable when a company is committed to high-quality CED (Bui et al., 2021). The report should be comprehensive, as well as include well-integrated information and independent assurance to evaluate specific disclosures to ensure that the VCED is of the highest quality (Pitrakkos and Maroun, 2019). The VCED should make a clearer distinction between “soft disclosure” and “hard disclosure” items, as the latter is easier to imitate because there is general rhetoric pertaining to it (Borghesi et al., 2018). Therefore, such disclosure practises may help to reduce the discrepancy between improving a company's reputation and its dedication to carbon reduction initiatives.

Researchers have conducted several bibliometric analyses, but they mainly concentrated on carbon emission research. For example, Udara et al. (2019) used scientometric analysis to review a body of research on carbon emissions from 1981 to 2019 that was sourced from the Web of Science database. Findings revealed a rising trend in publications in the field of carbon emissions, particularly from 2016 to 2018. It was discovered that calculating carbon footprints and assessing GHG emissions are common research topics. Shi and Yin (2021) clarified various analytical viewpoints on carbon footprint research by examining 7450 related articles from 1992 to 2019 by conducting a bibliometric analysis and developing a knowledge graph. They concluded that since 2008, the study

on carbon footprints has entered a new phase and it exhibits a significant trend towards interdisciplinary development.

An analysis of the literature on carbon, management, and accounting by Tuesta et al. (2022) looked at 95 academic papers published as of April 2020. While the earliest works date back to 2005, there were 32 papers published in 2017 and 2018, indicating a growing scientific interest in the topic. Furthermore, 36 articles on environmental disclosure literature were published by the top journal *Business Strategy and the Environment*, while the *Journal of Cleaner Production* published 23 high-impact factor articles. The most frequently used keyword by authors in environmental disclosure literature is “environmental disclosures” (203 occurrences), whereas, only 17 occurrences of the word “climate change” were reported. The study had conducted extensive research on different dimensions of environmental disclosures with 4053 citations for the papers. Based on what they found, the authors suggested that research hubs should work with the relevant departments for developing economies to set standards for climate change and bring together policymakers from developing and developed economies to work on climate issues.

### 3. METHODS

#### 3.1. Bibliometric Assessment

Bibliometric analysis is a pioneering and meticulous technique for investigating and analysing scientific evidence. It assists researchers to explore the subtleties of a discipline’s evolutionary history while illuminating the newly discovered area of the study (Donthu et al., 2021). Linnenluecke et al. (2020) argued that a bibliometric assessment is a scientific method for analysing published reading materials, such as books, journals, and other publications, using appropriate statistical tools. Citation Analysis, as a specialized analytical tool, is a component of the bibliometric method based on citation graphs that effectively refer to a network or graphical representation of citations in a document. It is widely used in the field of library and information sciences. This phase allows for impact assessments on various topics, including the chosen field of study, the researchers themselves, published materials, and efforts to identify the most significant papers related to a specific area of study (Ellegaard and Wallin, 2015). This research employed bibliometric and content analyses to describe and envision the intellectual structure and growth of carbon emission disclosure studies throughout the last 69 years.

#### 3.2. Procedure Analysis

Data search was conducted on December 7<sup>th</sup>, 2021 and involved the Scopus database. The search was based on articles whose titles contained words such as “Carbon emission disclosure” OR “Carbon reporting” OR “CO<sub>2</sub> reporting” OR “CO<sub>2</sub> emission disclosure” OR “Carbon disclosure” OR “Carbon accounting” OR “Environmental reporting” OR “Environmental information disclosure” OR “Greenhouse gas\* emission reporting” OR “Greenhouse gas emission disclosure” OR “Greenhouse gases disclosure” OR “Climate change disclosure” OR “Carbon disclosure project\*” OR “Climate change reporting” OR “Climate risk\* disclosure” OR “Climate-related risk\*” OR “Climate-related financial disclosure” OR “CDP Reporting” OR “Energy and

carbon disclosure” OR “Energy and carbon reporting” OR “Energy accounting” OR “Streamlined energy and carbon reporting” OR “GHG emission reporting” OR “carbon footprint reporting. The retrieved data was limited to article papers written in English only. The data search process is shown in Figure 1.

#### 3.3. Data Analysis

This study collected 745 documents from the Scopus database and the entries yielded authors’ names, papers’ titles, abstracts, keywords, year of publication, and cited references in plain text format, among other publishing metadata. These data were collected using network analysis, descriptive analysis, content analysis, and bibliometric analysis. Descriptive analysis was used to calculate data frequencies based on the total number of articles published, including the yearly trend, the most active journals, the most prolific countries, and the most prolific author in the research area. As for the citation analysis, data on citation metrics and most popular academic papers on the research topic were collected using Harzing’s Publish or Perish software. In addition, the VOSViewer software was used to undertake network and bibliometric analyses. The software calculated the weighted degree of centrality, degree of centrality, Eigenvector analysis, PageRank, and betweenness centrality for this study. This software was also used to analyse citations, co-citations, literature classification, co-authorship, keyword co-occurrence, and phrase co-occurrence. A cluster and gap analysis were also performed as part of the content analysis. Figure 2 illustrates the research structure of this study.

### 4. RESULTS

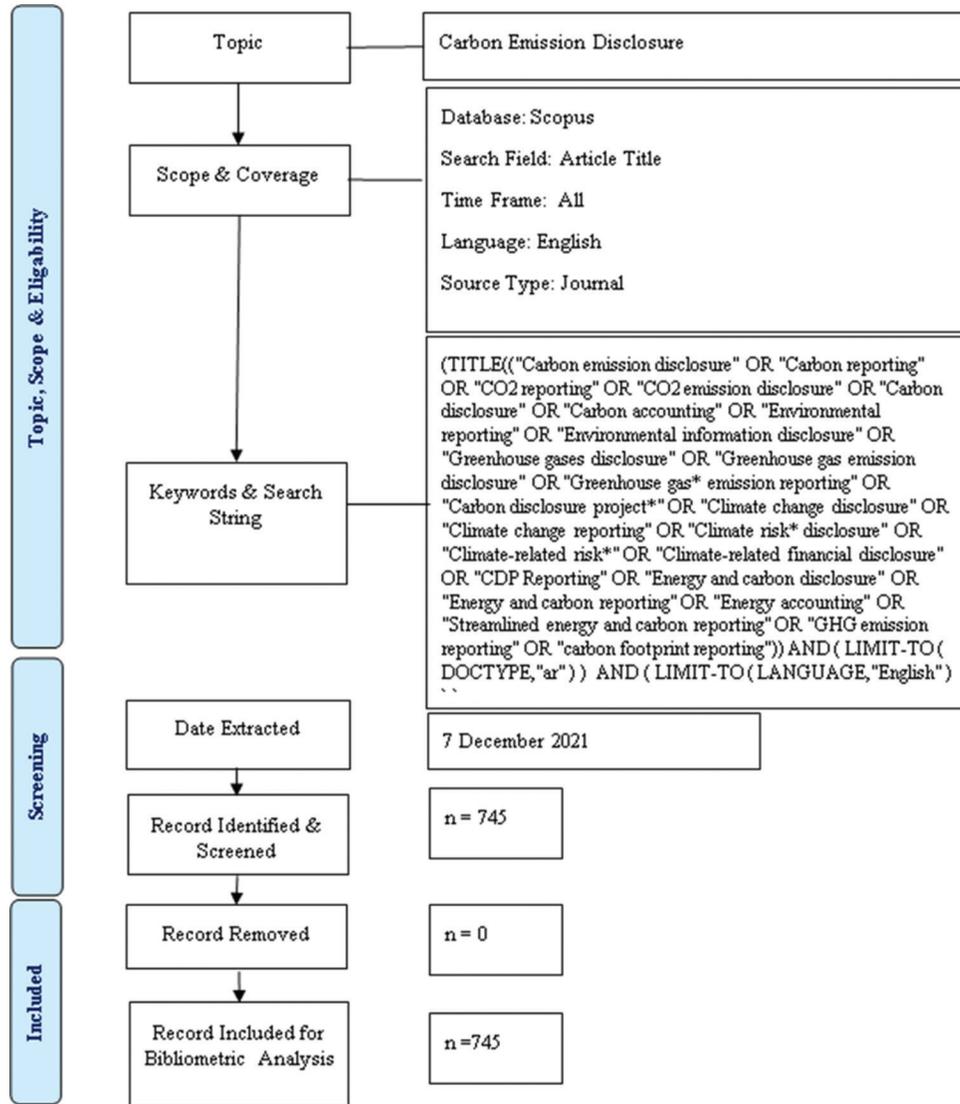
#### 4.1. Publication by Year

To address RQ1, the research trend based on the year of publication was monitored. Figure 3 shows the research trend regarding carbon emission disclosure publications and citations. Using Harzing’s Publish or Perish software, it was found that M.J. Lacopo was the first author to publish a paper on the study topic entitled “Interconnected Systems Energy Accounting Procedure and Related Operating Practices.” Before 1993, there were approximately 3 articles published on carbon emission disclosure in related journals. In 1994, publications increased since the UNFCCC, also known as “The Convention,” came into force on March 21<sup>st</sup>, 1994. The UNFCCC’s ultimate goal is to prevent “dangerous” human interference with the climate. It is overwhelming to discern that the publications (9 articles) in 1995 had 1,731 citations. In 2010, there was a significant increase in publications (23) relating to the research topic. It is believed that the researchers had begun to realise the significance of disclosing carbon emissions on a worldwide scale. Furthermore, enforcement of the Kyoto Protocol in 2005, which aimed to curb greenhouse gas emissions, might have attracted researchers to study carbon emission disclosures by companies across the world.

#### 4.2. “Publishing Activity by Country

This study also looked at countries that were actively involved in publications related to the research topic. Ninety-seven (97) countries support the research on carbon emission disclosure. The frequency data on nations engaged in the publication were computed using MS Excel, and the findings are shown in Table 1. 10 countries that

Figure 1: Diagram of the search process



Source: Modified from PRISMA (Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097).

Table 1: Top ten countries that contributed to the publications

Country	Total publications	% (n=745)
Australia	121	16.24
United States	119	15.97
China	118	15.84
United Kingdom	103	13.83
Malaysia	32	4.30
France	30	4.03
Germany	28	3.76
Spain	25	3.36
Canada	24	3.22
Indonesia	20	2.68

ranked highest in contributions to the research topic were collated. Australia supplied the most articles concerning research on carbon emission disclosure (121:16.24%), followed by the United States of America (119:15.97%) publications, and China (118:15.84%). Based on the frequency data from MS Excel, total publications based on countries were mapped using the globe map, as shown in Figure 4.

### 4.3. Publishing Activity by Journal

The 745 articles gathered from the Scopus database were published in 160 publications. Table 2 depicts the most active during the COVID-19 pandemic (Journal in Banking). Each journal was analysed using SCImago Journal Rank (SJR), Source Normalized Impact per Paper (SNIP), and CiteScore. SJR measures the serial’s weighted citations, which is determined by the citing serial’s subject field and prestige (SJR).

SNIP metrics involve the comparison of actual citations received with citations expected for the topic field of the series. Finally, Cite Score displays the typical number of citations earned for each document published in the serial. According to the frequency statistics, the Journal of Cleaner Production was the most active in publishing carbon emission disclosure articles, publishing 40 (5.37%) articles between 1953 and 2022. The journal has a Cite Score of 13.1, an SJR of 1.937, and a SNIP of 2.475. Following that is Business Strategy and The Environment, which has published 31 (4.16%) articles, and the Journal of

Figure 2: Structure of the research

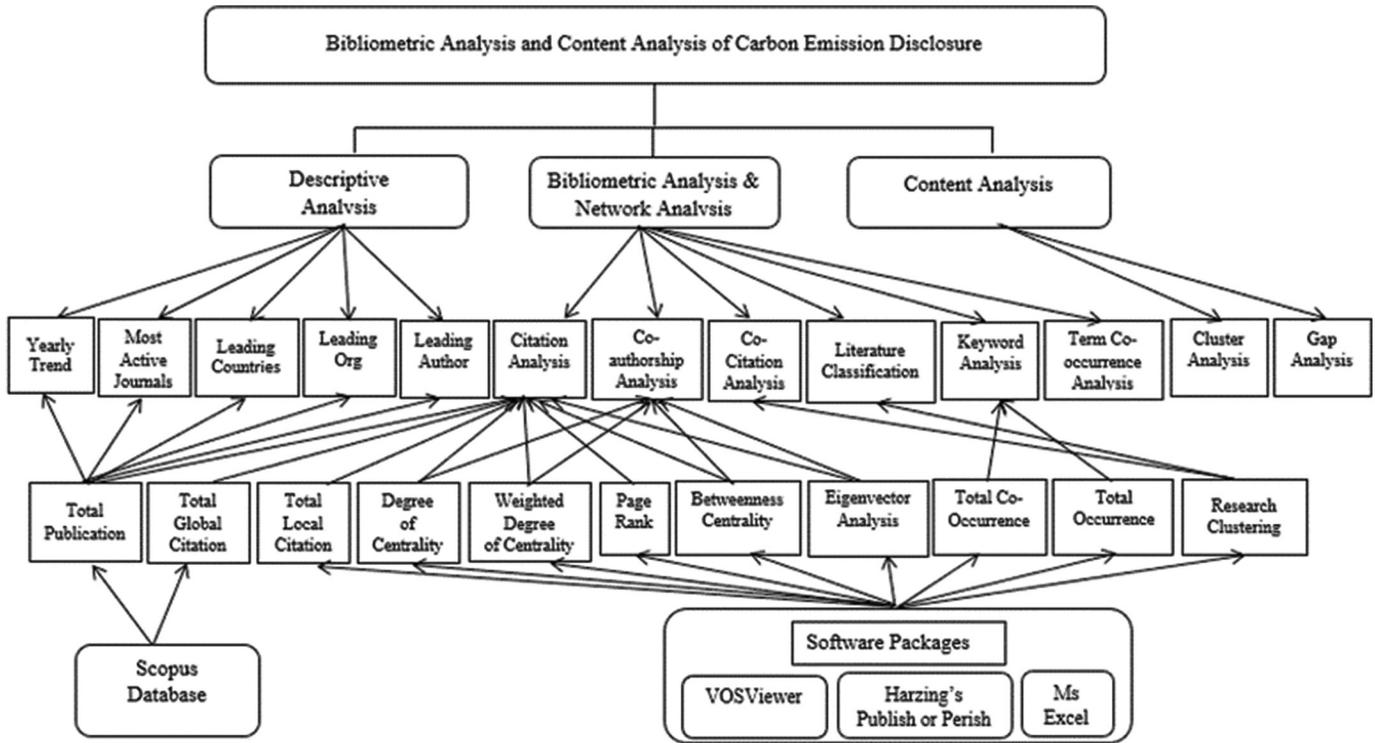


Figure 3: Total yearly publications and citations

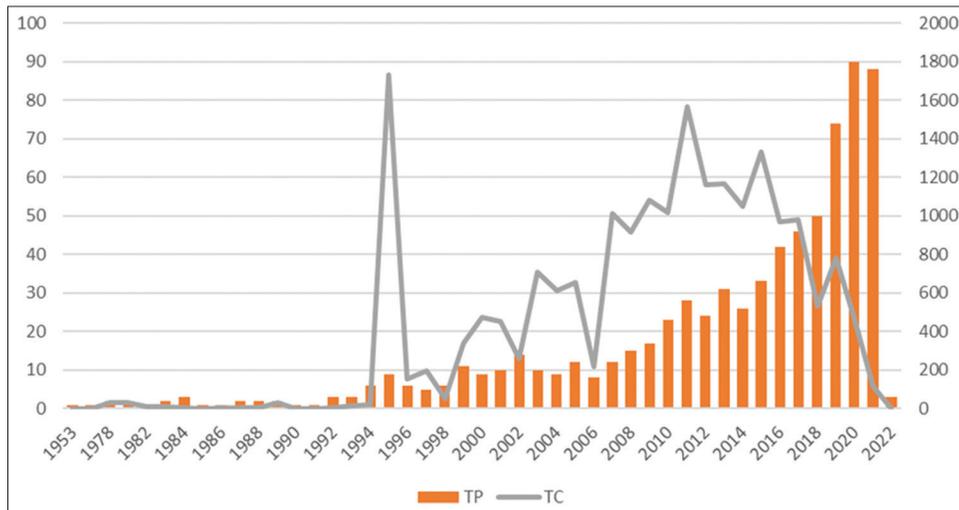


Table 2: Most active source title

Journal	Total publications	% (n=745)	Publisher	Cite Score	SJR 2020	SNIP 2020
Journal of cleaner production	40	5.37	Elsevier	13.1	1.937	2.475
Business strategy and the environment	31	4.16	Wiley -Blackwell	10.3	2.123	2.598
Social and environmental accountability journal	21	2.82	Taylor and francis	2.0	0.361	0.517
Sustainability switzerland	19	2.55	Multidisciplinary digital publishing institute (MDPI)	3.9	0.612	1.242
Accounting auditing and accountability journal	18	2.42	“Emerald”	6.0	1.741	1.888
Journal of business ethics	15	2.01	“Springer nature”	9.0	2.209	2.534
Corporate social responsibility and environmental management	14	1.88	Wiley-blackwell	8.0	1.519	2.277
Sustainability accounting management and policy journal	13	1.74	Emerald	3.6	0.619	0.937
British accounting review	11	1.48	Elsevier	7.0	1.223	2.111
Accounting forum	8	1.07	Elsevier	4.6	0.942	1.41

Social and Environmental Accountability, which has 21 (2.82%) publications.

**4.4. Publishing Activity by Author and Organisation**

This study also observed authors who were active in the research topic and institutions engaged in the publications. According to information obtained from the Scopus database, 1,733 authors from 160 different organisations contributed to the publications that dealt with carbon emission disclosures. The number of authors who had contributed to each article was also determined and the results are shown in Table 3. 209 (28.05%) of the 745 articles obtained from the Scopus database were written by two authors.

**Table 3: Number of the author (s) per document**

Authors count	Total publications	% (n=745)
1	140	18.79
2	209	28.05
3	187	25.10
4	111	14.90
5	47	6.31
6	26	3.49
7	7	0.94
8	3	0.40
9	5	0.67
10	1	0.13
12	1	0.13
13	1	0.13
15	1	0.13
0	6	0.81

The second-highest number of authors involved in a publication is three, with 187 (25.10%) articles. However, this study was unable to determine the number of authors for six publications as the Scopus database could not provide the information. Table 4 lists the top ten authors in terms of output. According to the data, the most productive author is L. Lebel of Chiang Mai University in Thailand, who authored seven publications (0.94%). P. Lebel, also of Chiang Mai University in Thailand, and Q. Tang, of Western Sydney University in Australia, had both contributed 7 (0.94%) papers to the research topic.

Data show that 160 organizations were involved in publications concerning the study topic. In order to answer the RQ, MS Excel was used to calculate the frequencies and the list of the most influential institutions, as shown in Table 5. The University of South Australia is the most significant contributor to the research field, with 13 (1.74%) publications over 69 years, followed by the Australian National University (13:1.74%) and the University of Newcastle (11:1.48%), also located in Australia.

**4.5. Citation Network Analysis**

This study expected to identify the most significant publication based on RQ2 (Which are the most influential articles on carbon emission disclosure?). Thus, in order to answer the RQ, citation networks of 745 publications were examined.

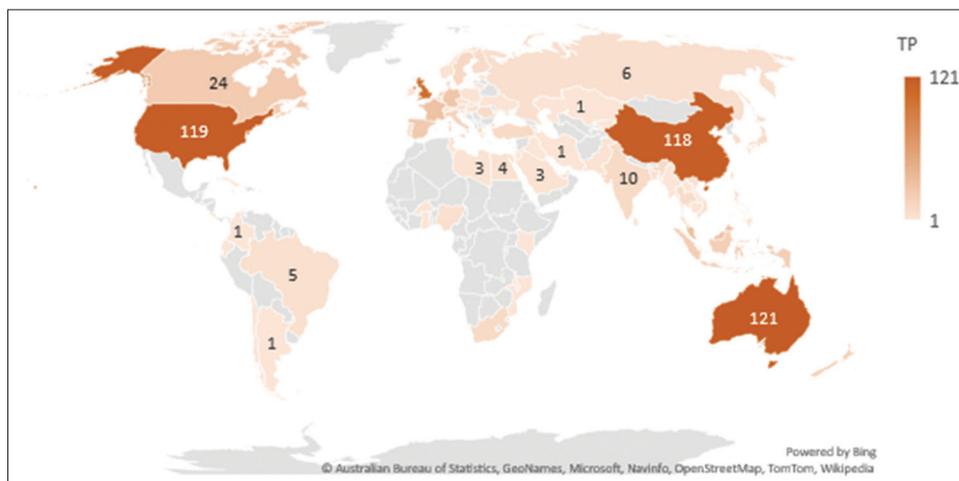
*4.5.1. A centrality analysis of citation networks*

To perform the centrality analysis of citations and construct a network visualisation map of the article’s citations, the Harzing

**Table 4: Most productive authors**

Author name	Total publications	%	Affiliation	Country
Lebel, L.	7	0.94	Chiang Mai University	Thailand
Lebel, P.	7	0.94	Chiang Mai University	Thailand
Tang, Q.	7	0.94	Western Sydney University	Australia
Luo, L.	6	0.81	Macquarie University	Australia
Amran, A.	5	0.67	Universiti Sains Malaysia	Malaysia
Patten, D.M.	5	0.67	Illinois State University	United States of America
Alrazi, B.	4	0.54	Universiti Tenaga Nasional	Malaysia
Borghei, Z.	4	0.54	Macquarie University	Australia
Bui, B.	4	0.54	Macquarie University	Australia
Deegan, C.	4	0.54	University of Tasmania	Australia

**Figure 4: Total publication by country**



Publish or Perish and VOSViewer tools were used. Table 6 shows the citation metrics data for the publications. As for the 745 articles on carbon emission disclosure, there were 20,151 citations. The typical number of citations per year is 296, with each document receiving an average of 27.

This study found papers that had received the most references by using information from the Scopus database. The list of highly referenced publications on the research topic is shown in Table 7. R. Gray, R. Kouhy, and S. Lavers wrote the most cited article entitled “Corporate social and environmental reporting: A review of the literature and a longitudinal study of UK disclosure,”

which was published in 1995 and had 1,623 citations. Next was the paper entitled “Corporate environmental reporting: A test of legitimacy theory,” by T.D. Wilmshurst and G.R. Frost, with 388 citations.

The minimum number of document citations was set to 1. The network visualisation map was created and viewed using the VOSViewer software. As a result, 622 papers out of 745 met the criterion, but only 404 were related and grouped into 25 clusters. Figure 5 depicts a network diagram of document citations. The publication entitled “Corporate social and environmental reporting: A review of the literature and a longitudinal study of UK disclosure,” written by R. Gray, R. Kouhy, and S. Lavers in 1995, is marked with the largest circle on the network visualisation map. This demonstrates that it is the most cited article in publications concerning the study topic.

**Table 5: Most influential institutions**

Institution	Total publications	% (n=745)	Country
University of South Australia	13	1.74	Australia
The Australian National University	12	1.61	Australia
The University of Newcastle, Australia	11	1.48	Australia
Universiti Teknologi MARA	10	1.34	Malaysia
Macquarie University	10	1.34	Australia
Western Sydney University	9	1.21	Australia
Universiti Tenaga Nasional	8	1.07	Malaysia
CSIRO Land and Water	8	1.07	Australia
China University of Mining and Technology	8	1.07	China
Chiang Mai University	7	0.94	Thailand

**Table 6: Citations metrics**

Citation metrics	Data
Papers	745
Citations	20151
Years	68
Annual Citations	296.34
Citations per paper	27.05
Citations per author	8750.46
h-index	74
g-index	120

**4.6. PageRank Analysis**

According to Ding et al. (2009), PageRank complements citation analysis by helping to search for publications referred to by highly cited papers. A network visualisation map was constructed to indicate the relationship between the cited articles and journal authors pertaining to the research issue. Figure 6 depicts the network visualisation map for document citations by country. The minimum number of articles and citations for a country was set at one. There are 97 countries active in research-related publications; however, only 78 countries met the requirement, while 64 countries were linked and organised into 14 clusters. On the network visualisation map, Australia is marked with the largest circle, which demonstrates that articles published by Australian writers are the most cited in publications concerning the study topic. According to the network visualisation map, other articles on carbon emission disclosure consistently cited 121 documents produced by Australian authors with 50 links. Hence, by referring to the other significant circles on the network visualisation map, this study found papers written by authors from the United States of America (118 documents, 40 links), China (118 documents, 35 links), and the United Kingdom (102 documents, 47 links), that were frequently cited.

**Figure 5: Network visualisation map of citations by documents**

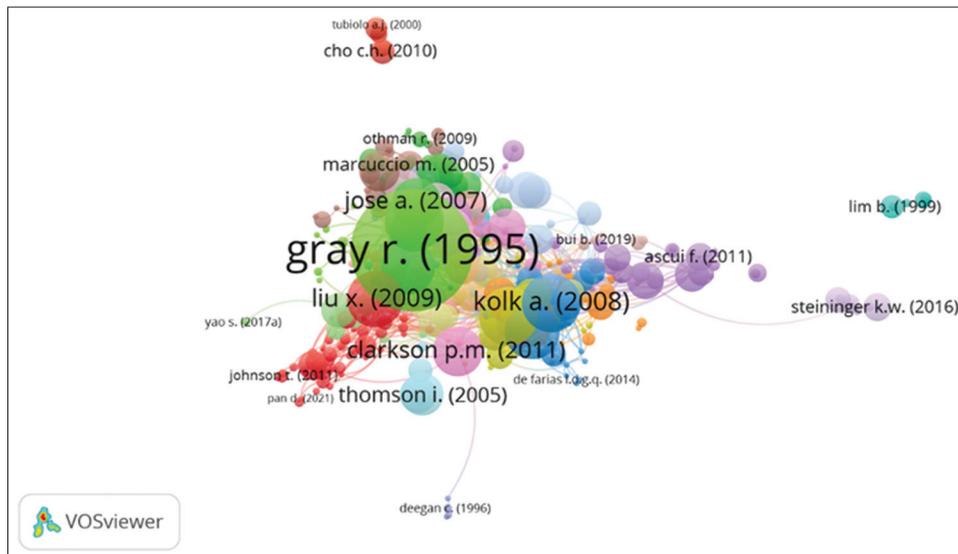


Figure 6: Network visualisation map of citation by country

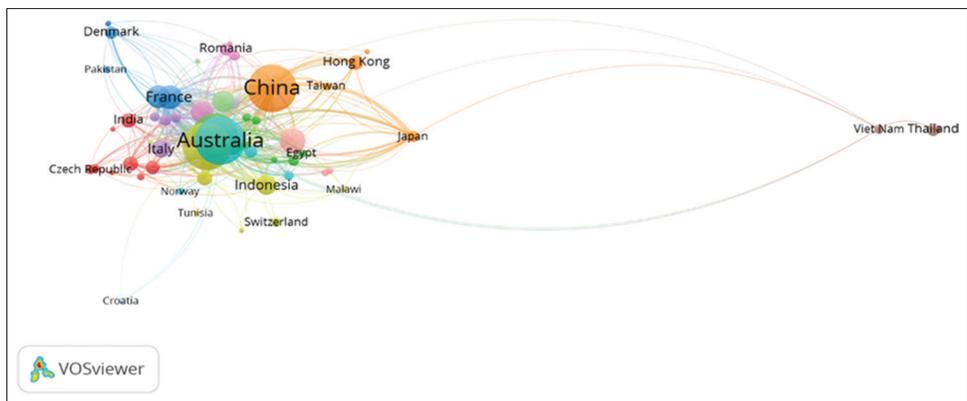


Table 7: Highly cited publications (above 200 citations)

	Authors	Title	Year	Journal	Citations	Citations per paper	Citations per author
1	R. Gray, R. Kouhy, S. Lavers	“Corporate social and environmental reporting...”	1995	“Accounting, Auditing and Accountability Journal”	1623	62.42	541
2	T.D. Wilmshurst, G.R. Frost	“Corporate environmental reporting: A test...”	2000	Accounting, Auditing and Accountability Journal	388	18.48	194
3	A. Kolk, D. Levy, J. Pinkse	“Corporate responses in an emerging climate regime...”	2008	European Accounting Review	386	29.69	129
4	L. Liao, L. Luo, Q. Tang	“Gender diversity, board independence, environmental committee...”	2015	British Accounting Review	381	63.5	127
5	X. Liu, V. Anbumozhi	“Determinant factors of corporate environmental information disclosure...”	2009	Journal of Cleaner Production	348	29	174
6	E.M. Matsumura, R. Prakash, S.C. Vera-Muñoz	“Firm-value effects of carbon emissions...”	2014	Accounting Review	328	46.86	109
7	D. Cormier, M. Magnan	“Environmental reporting management...”	2003	“Journal of Accounting and Public Policy”	326	18.11	163
8	P.M. Clarkson, M.B. Overell, L. Chapple	“Environmental Reporting and its Relation...”	2011	Abacus	273	27.3	91
9	A. Jose, S.-M. Lee	“Environmental reporting of global corporations...”	2007	Journal of Business Ethics	270	19.29	135
10	T. Tagesson, V. Blank, P. Broberg, S.-O. Collin	“What explains the extent and content of social and environmental...”	2009	“Corporate Social Responsibility and Environmental Management”	255	21.25	64
11	I. Thomson, J. Bebbington	“Social and environmental reporting in...”	2005	Critical Perspectives on Accounting	208	13	104
12	W. Ben-Amar, M. Chang, P. McKelney	“Board Gender Diversity and Corporate Response...”	2017	Journal of Business Ethics	205	51.25	68

4.7. Keywords and Co-occurrence Analysis

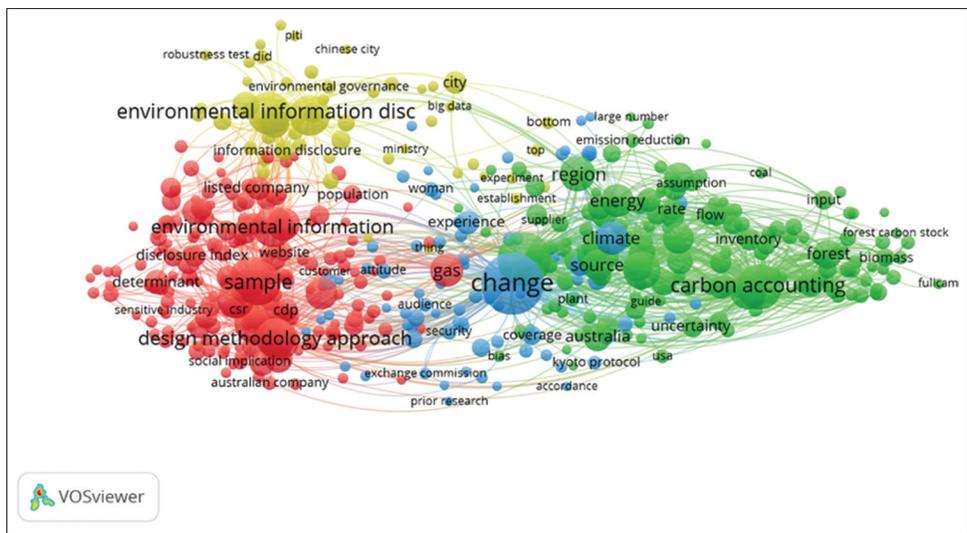
When two keywords coexist in a writing and indicates that two ideas are related, then, this is referred to as co-occurring keywords (Baker et al., 2020). In response to RQ3 (What are the most common academic carbon emission disclosure topics?), this current study aimed to determine the most frequently used keywords by researchers investigating carbon emission disclosures. Data frequencies of keywords employed in the research topic were calculated using MS Excel and the results are displayed in Table 8. “Climate change” is the most frequently

used keyword in carbon emission disclosures (136: 18.26%), followed by “Environmental Reporting” with 83 (11.14%) and “Carbon” 78 (10.47%).

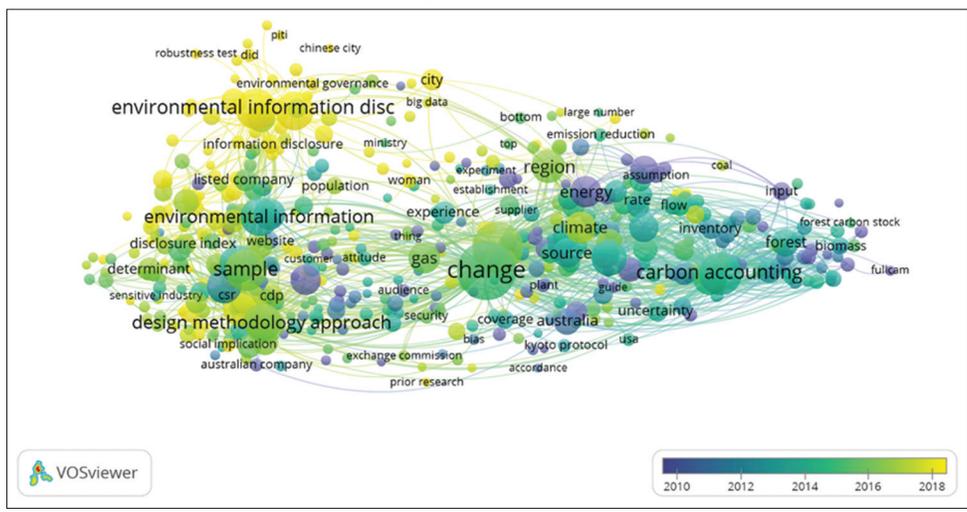
This study also ran the keyword co-occurrence analysis using the VOSViewer software to build a network visualisation map. Fractional counting was used and the minimum number of occurrences was set at two per publication. 313 keywords met the criterion out of 1,671; however, only 307 were related. Therefore, it was decided to create a network visualisation map



**Figure 8:** Network visualisation map of term co-occurrence of title and abstract field



**Figure 9:** Overlay visualisation map of term co-occurrence of title and abstract field



**4.8.1. Centrality analysis of the co-authorship network**

Figure 10 depicts a network visualisation map of co-authorship by authors in carbon emission disclosure articles. Fractional counting was employed and the minimum number of papers and citations was set at two. 1,448 authors out of 1,733 met the criteria. However, just 178 are connected as indicated in the 19 clusters shown on the network visualisation map. This demonstrates the collaboration among writers in their respective area of research.

Additionally, this study produced a network visualisation map based on country co-authorship. Fractional counting was used and a country needed have a minimum of 1 document and citation. Only 64 out of 97 nations that participated in carbon emission disclosure publication met the threshold, leaving 78 behind. Figure 11 shows the network visualisation map for co-authorship by country with 10 clusters. Based on the largest circle in the network visualisation map, it was found that authors from China, Australia, United Kingdom, and the United States of America collaborated with other countries on the research topic. Furthermore, the network visualisation map shows that authors from the United Kingdom (102:49 link strength) and China (118:41

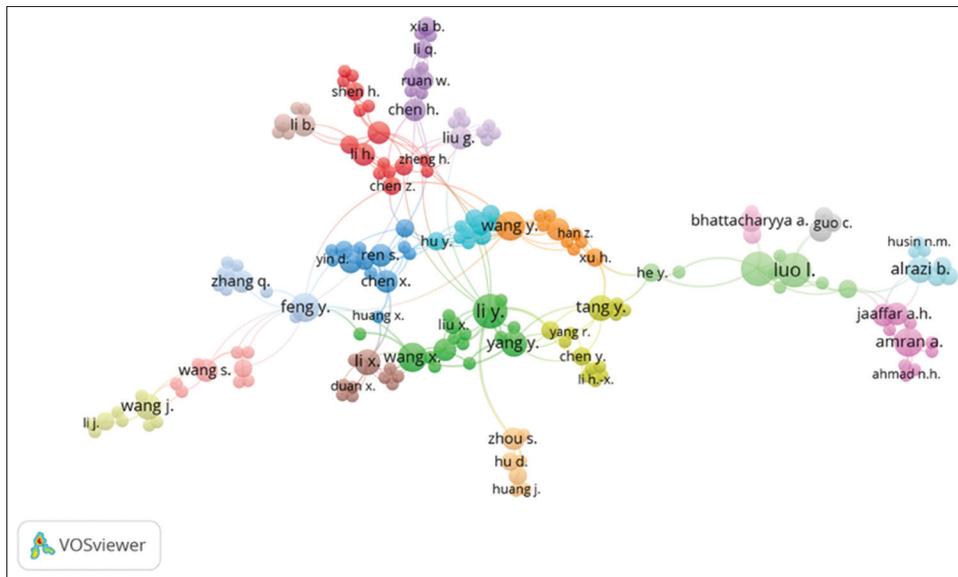
link strength) have a significant co-author link with authors from other nations, including Australia, France, Germany, Malaysia, and the United States of America.

**4.9. Co-citation Analysis**

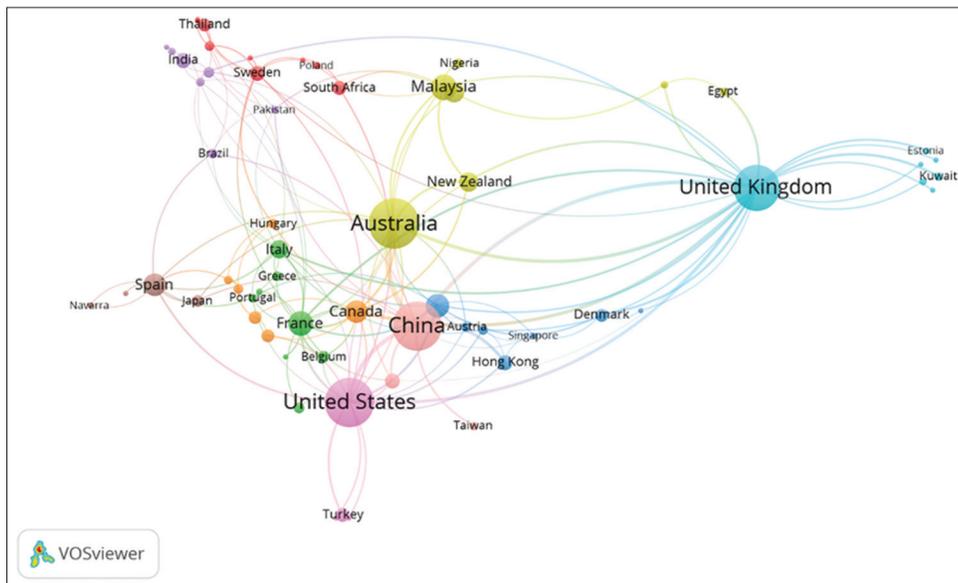
Co-citation is the process of citing two articles frequently together (Small, 1973). Co-citation analysis in bibliometrics could indicate the intellectual organisation of an area of study (Rossetto et al., 2018). According to Liu et al. (2015), it is also beneficial to highlight the direction, structure, and advances in a study domain. Using co-citation analysis, this study focused on understanding the intellectual framework of the study’s issue in order to answer the RQ.

A network visualisation map was created using the VOSViewer software to observe the co-citation network among the cited authors in publication related to the study topic. Fractional counting was used and a minimum requirement of ten author’s citations was set. Figure 12 depicts the co-citation network based on cited authors. Out of the 31,911 authors who submitted their papers, 1168 met the criteria and 1165 were related. There are

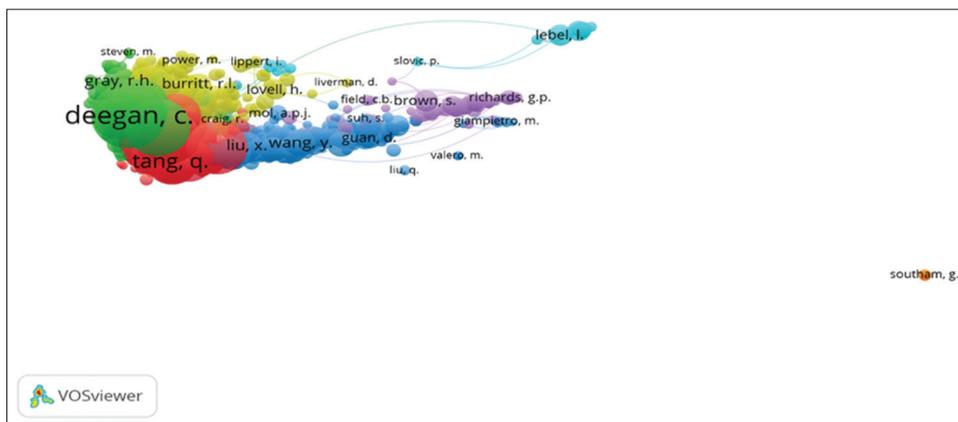
**Figure 10:** Network visualisation map of co-authorship by authors



**Figure 11:** Network visualisation map of co-authorship by countries



**Figure 12:** Network visualisation map of co-citation of cited authors



seven clusters shown in the network visualisation map. Authors in the same cluster are thought to have referenced one another in

their papers. Each cluster usually represents a different discussion point on carbon emission disclosure.

#### 4.9.1. Literature classification

According to Radicchi et al. (2004), clustering has been used in previous studies on group research works. Data clustering, according to Xu et al. (2018), can be used in a co-citation analysis to identify patterns of collaboration and interrelationship. This current study conducted a co-citation analysis on the cited references using the VOSViewer software. Fractional counting was selected and the minimum number of cited references was set at 5. Out of 34,683 cited references, 193 met the threshold, with only 186 cited references connected. Figure 13 shows the eight clusters that were assigned with different colours each. Cluster 1 (red) listed 47 cited references based on the co-citation of cited references' network visualisation map. The most cited reference (29 citations) in Cluster 1 is an article entitled "Corporate responses in an emerging climate regime: The institutionalisation and commensuration of carbon disclosure" by A. Kolk, D. Levy, and J. Pinkse (2008). Cluster 2 (green) shows 34 cited references. An article by D. Nue, H. Warsame, and K. Pedwell (1998) entitled "Managing public impression: Environmental disclosures in annual reports" (29 citations) is the most cited article in Cluster 2. Cluster 3 (blue) shows 34 cited references, and D.M. Patten's article entitled "Intra-industry environmental disclosure in response to the Alaskan oil spill: A note on legitimacy theory", contained the most cited references. Cluster 4 (yellow) presents 28 cited references. The most cited reference in this cluster is "Revisiting the relation environmental performance and environmental disclosure: An empirical analysis," by P.M. Clarkson, Y. Li, G.D Richardson, and F.P Vavari (2008) (19 citations). Cluster 5 (purple) shows 22 cited references with the most citations appearing in an article entitled "A study of environmental disclosure practices of Australian corporations" by C. Deegan and B. Gordon (1996) (32 citations). Cluster 6 (light blue), with ten cited references, showed the most cited reference appearing in an article entitled "The role of environmental disclosures as tools of legitimacy: A research note", by C.H. Cho and D.M. Patten (2007). Cluster 7 (orange), with eight items, indicated that an article by R. Hahn and M. Kuhnen, entitled

"Determinants of sustainability reporting: A review of results, trends, theory and opportunities in expanding field of research" (2013), was the most cited reference in this cluster (11 citations). Cluster 8 (brown) shows three cited references and the article by J. Wiseman (7 citations) entitled "An evaluation of environmental disclosures made in corporate annual reports in 1992", contained the most cited reference for this cluster.

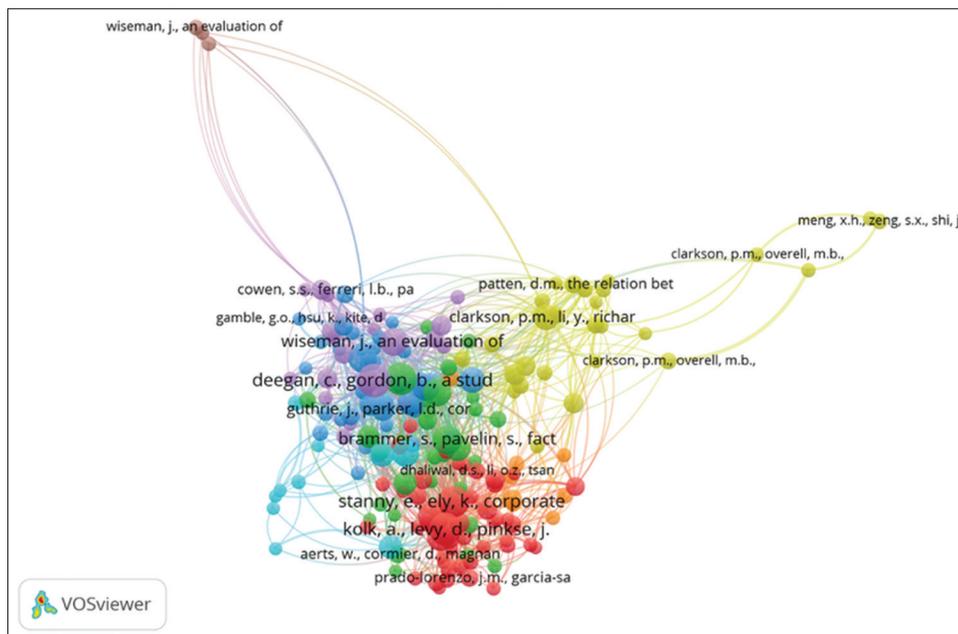
#### 4.10. Content Analysis

The co-citation network analysis revealed research clusters that contained a total of 504 studies. The co-citation data were further examined to address RQ 6 (Which conceptual framework drives present carbon emission disclosure?). A content analysis was conducted based on the co-occurrences of the title and abstract fields, which refer to the highlighted topics. Four clusters were detected in the network visualisation map (Figure 10). Ten (10) papers were chosen from each cluster for the content analysis based on their highest citation count. This research is organized into four broad groups. Cluster 1 (red cluster) is concerned with environmental information and performance, Cluster 2 is about carbon accounting and emissions, Cluster 3 contains articles that discuss climate change and Cluster 4 is also concerned with the disclosure of environmental information.

##### 4.10.1. Cluster 1(red): Environmental information among companies

Many factors influence the environmental information given by companies. Findings indicate that the more information about environmental investment and pollution control costs are disclosed, the better the company's economic performance. In addition, when the economy is sufficiently developed, businesses are more likely to share information regarding emissions (Liu and Anbumozhi, 2009). Conversely, a number of studies suggest that the nature of disclosures is influenced by each nation's legislative and regulatory framework that regulates environmental activity and affects environmental performance.

Figure 13: Network visualisation map of co-citations of cited references



Theoretical factors are studied to determine if the various types of disclosures resulting from regulatory demands exhibit accountability related to environmental information disclosure and to what extent the disclosure discharges the organisation's responsibility to users of such information (Holland and Foo, 2003; Clarkson et al., 2011). Hence, certain studies may indicate a need for more significant reporting requirements and improved enforcement. The legitimacy theory, however, is only partially supported by studies when it comes to explaining the relationship between identified factors that influence management's decision-making and actual environmental disclosure. Researchers also investigated whether the corporate environmental information disclosure effort is essential in comparison to the roles of other stakeholders; nonetheless, the outcome was unfavourable. Studies have also proposed that the banking industry should stimulate environmental information disclosure. However, rather than enforcing environmental information standards, the bank is more concerned with maintaining its primary interest in protecting its loans (Thompson and Cowton, 2004).

#### 4.10.2. Cluster 2 (green): Carbon accounting and emissions

Improvements in reporting protocols for greenhouse gas emissions, specifically carbon disclosure, is a topic covered by researchers in their articles. Many studies in this cluster divided a company's various internal application areas and carbon accounting methodologies for the benefit of corporate decision-makers. Strategies for separating physical and monetary approaches in carbon accounting are reviewed in a structured manner in the environmental management accounting framework. As the range of carbon accounting procedures broaden to include product life cycles and supply chains, researchers are faced with the challenge of creating new carbon accounting systems. There has been a call for a definition of carbon accounting so that practitioners can use it to establish carbon accounting measures in businesses, legislators can use it to distinguish between mandatory and voluntary accounting, and academics can use it to operationalize their research questions. A fully functional carbon tracking system must be based on measurements that are extremely accurate, can account for data uncertainty, and be consistent over time and space. However, researchers believe that it will be challenging to accomplish these goals. This is because current efforts to account for carbon emissions are dispersed across three distinct organisational fields-the measurement of carbon emissions, social accounting methods, and accountability in the global carbon governance system-each of which places a different emphasis on objectives.

#### 4.10.3. Cluster 3 (blue): Climate change

The global scope of greenhouse gas emissions and the increasing severity of climate change consequences necessitates new and broader approaches to prevent and mitigate the negative effects of climate change. It implies enhanced methods for anticipating and meeting new information needs related to climate change. Some studies have looked into the impact of boardrooms on the company's responses to stakeholder requests for greater public disclosure of risks associated with climate change, such as carbon emissions. A market governance system's voluntary corporate greenhouse gas (GHG) reporting was explained by some research

using institutional governance theory in the absence of public policies addressing climate change (Rankin et al., 2011).

Studies have shown that the level of voluntary carbon disclosure depends on the company's visibility and the issue at hand (climate change). Researchers have also evaluated the role of green innovation (a formal internal mechanism) as a mediator in influencing a company's carbon disclosure. Studies have tried to learn more about the nature of emerging challenges, which are heavily influenced by risk and risk management discourse, and the discourse of private climate change reporting. This developing risk discourse stems from institutional investors' perception that climate change is a substantial risk, most pressing sustainability issue and their clients expect them to manage climate-related risk as part of their portfolio investment.

#### 4.10.4. Cluster 4 (yellow): Environmental information disclosure

Corporations will have to be more transparent about their climate change policies as carbon regulations change over time. Global environmental protection has made the achievement of high corporate environmental information disclosure levels a very difficult challenge. Stakeholders will demand that corporations give more information about their initiatives to reduce their carbon emissions. Clinical studies have aimed to identify factors that determine the degree of corporate environmental information disclosure. This cluster's research contributes to international research on a variety of issues. Some studies analysed the correlation between environmental information disclosures and firm variables, such as size, profitability, leverage, and the activity sector. There is an urgent need to standardise and strictly regulate the environmental information disclosure system used by public listed companies. Many studies have aimed to investigate and determine which factors contribute to the various levels of environmental information disclosure that can be recommended to policymakers. Despite the numerous issues discussed by the researchers, many agreed that there is an urgency to improve the way publicly traded companies share their environmental information.

### 4.11. Findings and Future Areas of Research

This section summarizes the study's results and suggests potential areas for research. This study also identified challenges faced by current researchers investigating this topic (Which difficulties impede research into carbon emission disclosure?). In the first phase, it was observed that recent studies on carbon emission disclosure were based on a descriptive analysis. Investigations into carbon emission disclosure started in 1953, and the number of publications increased significantly in 2007. This was probably due to the implementation of the Kyoto Protocol in 2005, which aimed to regulate and limit greenhouse gas emissions. The Paris Agreement in 2016 has boosted the attentiveness of researchers to examine how far the objectives set to limit climate change have been accomplishment.

The citation analysis revealed the most prominent article on carbon emission disclosure written by Gray et al. (1995) from Scotland, with 1,623 citations. However, the PageRank analysis

showed a contradictory finding, whereby authors from Australia had written the greatest number of publications on carbon emission disclosure. Even though the articles written by Liao et al. (2015) and Wilmshurst and Frost (2000) were cited 393 and 390 times, respectively, the papers were ranked higher than the most cited article, as reported previously, due to their contents. Furthermore, the keyword and occurrences analysis showed that “climate change” is the most popular keyword used by authors in publications on the research topic. It is understood that researchers investigating carbon emission disclosure frequently used the term “climate change” as it portrays the most accurate meaning. The Oxford Dictionary (2021) defines “climate change” as modifications to earth’s weather, such as variations in temperature, wind patterns, and rainfall, with a focus on the rise of specific gases, particularly carbon dioxide, that causes the earth’s atmosphere to warm up.

Analyses on co-authored works and their citations have revealed the collaboration and networking among the authors worldwide and the citation involved in their publications. Both analyses assisted this study in conducting a content analysis of the data gathered. The content analysis shows that studies on carbon emission disclosure are more concerned about environmental information provided by companies and the methods used to calculate emissions in carbon accounting and climate change. In addition, the studies mainly focused on different industries or countries due to the collaboration amongst authors from other developed countries.

This study suggested that future research should investigate the consistency of various consequences of carbon information disclosure provided by emerging and developed markets. Besides, the consistency of multiple implications accruing from disclosures by carbon-intensive and low-carbon businesses in developing nations could be an exciting avenue to explore. Studies could also examine the specific features of family firms in order to extend the definition of carbon information. In addition, future research could investigate dynamic changes when evaluating the amount of carbon emission that is required to be disclosed by companies. Finally, future research can review the optimal carbon disclosure level that can help avoid risks and opportunities presented by an uncertain climate.

## 5. CONCLUSION

Previous studies on carbon emission disclosures merely intended to improve the validity of carbon data reported by companies. This study’s findings showed that previous studies contributed to the field by analysing various factors and variables that significantly impact carbon information disclosure; however, the focus was on comparing different industries and countries. This study also highlighted the most reputable and significant studies related to carbon emission disclosures, which have a global impact on citations in other studies, although it does not necessarily reflect that. Keyword and term co-occurrence analysis have shown that previous studies over a span of 68 years had focused on climate change, environmental reporting and environmental information disclosures.

This study managed to divide previous studies into four clusters by conducting a content analysis, which helped highlight the popular keywords used by researchers in this field. Hence, factors analysed by previous studies that aimed to improve the validity of environmental information disclosure were elucidated by this study. However, this study’s data are restricted to the Scopus database, which future studies can expand by obtaining data from other databases. Future studies could also examine how the evolution of carbon accounting across different paradigms can help solve current problems faced by this field.

## 6. ACKNOWLEDGMENT

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