Carsharing services in sustainable urban transport: An inclusive science map of the field

Carsharing services in sustainable urban transport: An inclusive science map of the field

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Abstract

Vehicle sharing, electrification, and automation, as the triple revolutions in urban transportation, have been under debate towards a new transport paradigm. In this regard, carsharing services, as a potential solution for sustainable urban transport, have gained momentum within the context of sustainable cities in recent years. This research, as the first attempt in the literature, aims to render a comprehensive map of the body of knowledge in the carsharing field of research through conducting a systematic bibliometric analysis. To achieve that, a total of 729 peer-reviewed journal articles from the Web of Science database were scrutinized using keyword, text mining, and bibliographic coupling analyses. The analyses revealed four main research themes building the carsharing literature, including (1) collaborative consumption and carsharing business models development in the context of sustainable urban transport, (2) carsharing adoption with a special focus on user behavior, intention, and preferences, (3) carsharing operational challenges, considering infrastructure and fleet management, and (4) technological advancement towards deployment of shared autonomous vehicles and mobility as a service. The results showed that the carsharing literature lacks (i) a well-established and comprehensive long-term sustainability assessment framework, (ii) inclusive and integrative marketing and training plans, as well as effective incentives, (iii) a holistic analysis of the role of carsharing in the achievement of Sustainable Development Goals, (iv) reliable circular economy indicators designed to measure the circularity of carsharing to help transitioning towards a circular economy, and (v) a timely broad analysis on the implications of the COVID-19 pandemic and the future of carsharing post pandemic era, which call for more investigations in the future. The provided insights support both researchers and policy-makers by shedding light on carsharing services research by providing a state-of-the-art of carsharing studies and developments up to date, uncovering the emergent research themes and trends, and identifying research gaps for future studies towards better positioning carsharing services in sustainable cities developments.

Keywords: Car sharing, Shared mobility, Sustainable transport, SDGs, Urban transport

1. Introduction

In recent years, the concept of sharing economy has emerged as a new consumption style with the potential to support new production and effective use of products (Kurisu et al., 2021) through giving temporary access (i.e., without ownership transferring) enabled by using online platforms (Ranjbari et al., 2018). Due to the increasing population of urban areas, transport activities have become more critical than ever in developing sustainable cities action plans for local and regional governments and authorities (Martins et al., 2021). In this regard, carsharing services have gained momentum as a tool for transport policy-makers, since their improvements in the urban transport system can reduce the number of cars, leading to more sustainable cities (Ampudia-Renuncio et al., 2018). Carsharing, by providing the benefits of a private vehicle without owning it through sharing the vehicles by different drivers at different times, supports the transition of private mobility from ownership to service use (Shams Esfandabadi et al., 2020). Whether these services are provided through peer-to-peer (P2P) or business-to-consumer (B2C) platforms, carsharing consists of round-trip or one-way services in which vehicles are available for use without drivers. Therefore, carsharing differs from ride-hailing in that there is no driver to make a suitable trip for the service user, and differs from ride-sharing in that only the use of a vehicle is shared not a trip.

A substantial amount of scientific research on different aspects of carsharing has been conducted in the last decade. The major subject areas include but are not limited to business models (Münzel et al., 2019; Yun et al., 2020), sustainability aspects (Bocken et al., 2020; Hartl et al., 2018), operational challenges (Balac et al., 2019; Huang et al., 2018; Jian et al., 2016), adoption (Burghard and Dütschke, 2019; Chun et al., 2019; Ullah et al., 2019), demand (Li and Kamargianni, 2020; Zhang et al., 2019), technological advancements (Iacobucci et al., 2018; Vosooghi et al., 2020), and travel behavior (de Luca and Di Pace, 2015; Jain et al., 2020; Matowicki et al., 2021). Besides, few review articles have been published addressing different aspects of carsharing services, such as price and taxation levels (Schwieterman and Bieszczat, 2017), free-floating carsharing (Mattia et al., 2019), business models (Lagadic et al., 2019), vehicle relocation problem in one-way carsharing networks (Illgen and Höck, 2019), urban sustainability impacts (Roblek et al., 2021), and electric carsharing (Liao and Correia, 2020). Nevertheless, although shared mobility strategies such as carsharing have gained significant attention in research communities, even media, and public debate during recent years, the overall impact of the sharing economy model on transport is still blurred (Standing et al., 2018). Moreover, a holistic image of the carsharing research themes, hotspots, and tendencies is lacking within the fragmented literature of carsharing services. Therefore, to fill the identified gap, this systematic bibliometric review aims to provide a comprehensive map of the body of knowledge on carsharing services.

To the best of the authors' knowledge, this is the first systematic bibliometric analysis on carsharing services in the literature, which significantly contributes to the carsharing field of research through (i) analyzing hotspots and research tendencies in the carsharing literature employing keywords and text mining analyses, (ii) discovering the main research themes building carsharing research background applying a bibliographic coupling analysis, and (iii) identifying potential directions for future carsharing research. Hence, the following research questions (RQs) are formulated and answered in this study:

RQ1. How has the scientific production in the field of carsharing performed over time?

RQ2. What are the hotspots and tendencies of carsharing research?

RQ3. What are the major research themes building carsharing literature?

RQ4. What are the potential directions for future research on carsharing services?

The structure of the paper is as follows. Materials, methods, and the overall research framework are explained in Section 2. The main findings of the research are presented and discussed in three sub-sections, representing descriptive analysis: Publication developments (Section 3.1), carsharing research hotspots, tendencies, and orientations (Section 3.2), and major emergent carsharing research themes (Section 3.3). Section 4 provides the identified potential research direction for future studies on carsharing. Finally, Section 5 delivers the conclusions and limitations of the research.

2. Materials, methods, and research framework

In this research, a systematic bibliometric review was conducted by employing an analytical method adopted from Ranjbari et al. (2021a), combining keyword analysis, text mining analysis, and bibliographic coupling clustering to provide the state-of-the-art of carsharing research. The bibliometric analysis has been widely used by scholars over the recent years for science mapping and providing an inclusive overview of the body of knowledge in any scientific domain and discipline. The rationale behind adopting bibliometric analysis for achieving the main aim of the present review was its capability to first, map the underlying conceptual structure, dynamics, and paradigm developments (Krey et al., 2022), and second, deal more efficiently with a huge amount of documents based on statistical measurement compared with traditional literature reviews (Su et al., 2021).

Figure 1 illustrates the overall research framework design of this research corresponding to the research questions and expected results. The search protocol for data sampling, screening, and collection (Section 2.1), and methods of analyses (Section 2.2) are explained in detail in the following sub-sections.

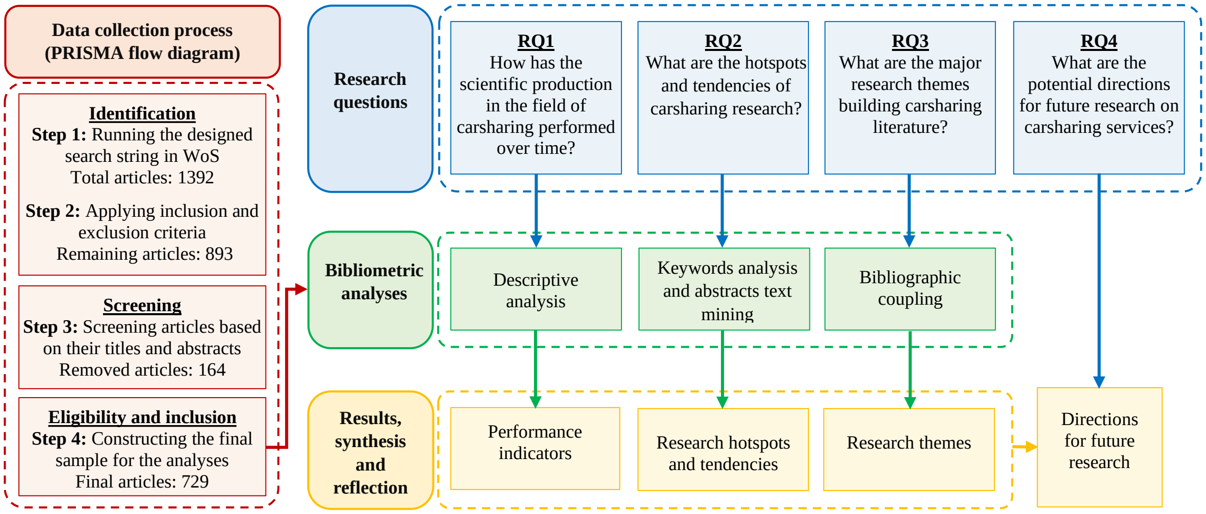


Figure 1. Research framework design.

2.1. Search protocol: Data collection process

Developing a suitable search protocol to collect as many relevant and reliable research articles as possible has been extensively highlighted in the literature as a crucial prerequisite for conducting comprehensive and systematic reviews (Chaudhary et al., 2021; Zahedi et al., 2016). On this basis, a search protocol based on the PRISMA statement framework (Liberati et al., 2009) was defined to better establish search boundaries and capture relevant articles from the target literature on carsharing research. In this regard, (i) formulating a well-defined search string, (ii) selecting a reliable database with sufficient coverage, and (iii) defining inclusion and exclusion criteria for collecting articles, are of most importance to ensure the quality of systematic reviews.

Since the concept of "carsharing", as the main focus of the present research, has been addressed by various terms and also different written forms in the literature (i.e., car sharing, car-sharing, and carsharing), the following search string combining all potential terms and words was designed: "carsharing" OR "car sharing" OR "car-sharing" OR "shared vehicle*" OR "car club" OR "shared-used car*" OR ("shared car*" AND "passenger*" AND "transport*"). The second part of the search string, which is in parenthesis, was limited with "passenger*" AND "transport*" to avoid capturing papers from clinical research studies referring to shared care or caring of patients in healthcare facilities. In the next step, the Web of Science (WoS) Core Collection citation database was considered as the main database for conducting this review.

The initial run of the search string in the topic of documents (i.e., title, abstract, author keywords, and keywords plus) returned 1,392 articles without any time limitation. No time limitation was considered to cover the whole scientific production up to date. Then, based on the defined inclusion criteria, only peer-reviewed journal articles in the English language were included in the sample. In this stage, other types of documents, such as conference proceedings, editorials, reports, book chapters, etc. were excluded from the data, leading to removing 499 documents. The titles and abstracts of the remaining 893 articles were manually checked to see whether they are relevant to the focus of this review. On this basis, 164 articles that mainly had focused on other types of shared mobility services, such as bike-sharing, scooter sharing, bus, and ride-hailing were excluded from the sample. As a result, a total of 729 articles published from 1980 to 2021 were selected as the base for the present review. The details of the adopted search protocol to collect the final sample for analysis are tabulated in Table 1.

Table 1

The search protocol and data collection process information.

Search string	"carsharing" OR "car sharing" OR "car-sharing" OR "shared vehicle*" OR "car club" OR "shared-used car*" OR ("shared car*" AND "passenger*" AND "transport*")
Database	WoS Core Collection
Search field	Title, abstract, author keywords, and keywords plus
Initial result	1,392 records
Inclusion criteria	(i) English documents, (ii) peer-reviewed journal articles and reviews

Second result	893 articles
The last update	July 1, 2021
Screening stage	164 articles were removed
Final sample	729 articles

2.2.Analysis methods

To scrutinize the carsharing literature corresponding to the RQs of this study, a systematic review was conducted through using descriptive analysis, keyword analysis, text mining analysis, and bibliographic coupling analysis in four phases.

First, a descriptive analysis was conducted to present the performance indicators of scientific production in the field of carsharing, addressing RQ1. On this basis, bibliometric information was extracted from the target literature, including time trends of publication, core journals, and geographical distribution of contributing countries to carsharing research development over the last four decades.

Second, keyword analysis of the author keywords of the articles (N= 1,674) was combined with a text mining analysis on the concatenation of the titles and abstracts of the articles (N= 729), to identify the hotspots, research tendencies, and theoretical orientations of carsharing research which has been conducted so far, addressing RQ2. Keywords defined by the authors of an article reflect the core concepts of the research (Chiang, 2020). In this phase, keywords were analyzed based on their occurrence, co-occurrence (i.e. joint occurrence of different keywords in the same paper), and time overlay to map the intensity of keywords and also mutual interconnections between them (Mustak et al., 2021). As a crucial step before conducting keyword-based analyses, a data cleaning on the author keywords was done to increase the reliability of the analysis (Ranjbari et al., 2020). In this vein, the following settings were performed: (i) keyword abbreviations and their full forms were merged, (ii) singular and plural forms of the keywords were considered the same to avoid duplicating, (iii) the American and British writing styles were unified based on the American style, and (iv) parentheses within the keywords were removed.

However, to enrich the knowledge obtained from the keyword-based analysis, as a type of quantitative content analysis (Weismayer and Pezenka, 2017), further studies can be conducted on the titles and abstracts of the articles to extract more information about the topics explored by the researchers. In this regard, text mining techniques have been extensively used by researchers to analyze the research tendencies and orientation of scholars through extracting context and meaning from the text of a huge collection of scientific documents (Jung and Lee, 2020). Text mining, as a knowledge discovery process (Usai et al., 2018) from unstructured data (Delen and Crossland, 2008), provides an opportunity to extract meaningful terms and patterns from the title and abstract texts of the articles. This process is different from data mining in that in the latter, the patterns are extracted from structured data (i.e. keywords in our case) (Demeter et al., 2019). Therefore, the text mining analysis based on the term co-occurrence algorithm (Van Eck and Waltman, 2011) was carried out to identify phrase patterns, semantic structures, and latent research orientations, which best characterize the body of knowledge in extant carsharing research. The VOSviewer software version 1.6.16, which is a Java-based computer program developed by van Eck and Waltman (2010) to visualize node-link maps within the documents based on bibliographic data, was used for conducting bibliometric and text mining analyses in this phase.

Third, due to the large number of articles (N=729), a data clustering technique using bibliographic coupling networks was carried out to group the articles based on the bibliographic coupling links (i.e., the number of times that every two articles have simultaneously cited another article). Hence, a bibliographic coupling analysis using VOSviewer was performed to uncover the main research themes building carsharing literature, addressing RQ3. The bibliographic coupling clustering of articles, as one of the more accurate bibliographic techniques to quantitatively assess the relatedness between two scientific documents, with a forward-looking perspective leads to unfolding the more recent research themes (Belussi et al., 2019) within the carsharing research domain up to date. The bibliographic coupling module of VOSviewer provides a map of clusters automatically based on the data presented to the software. However, since the process is conducted through a machine-driven algorithm, as proposed by van Eck and Waltman (2017), different values for the resolution parameter (Waltman et al., 2010) were tested to achieve a satisfactory level of detail in clustering. As a result, the number of clusters was decided to be four as a further breakdown of the network did not add any further homogeneous topics.

Finally, based on the provided insights by the two aforementioned analyses, potential directions for future research on carsharing services were proposed to answer RQ4.

3. Results and discussion

To clearly address the RQs of the present review, the results are presented in the following three subsections. On this basis, Section 3.1 presents the descriptive analysis to answer the RQ1, including publication evolution over time, main contributing journals to the carsharing research area, and geographical distribution of publications. RQ2 is answered in Section 3.2, which delivers the discovered research hotspots, tendencies, and orientations within the carsharing literature. Finally, the results of the bibliographic coupling analysis are provided in Section 3.3 to address the RQ3.

3.1. Descriptive analysis: Publication developments

The performance indicators of carsharing scientific production are presented in this section to address the first RQ of this study:

RQ1. How has the scientific production in the field of carsharing performed over time?

3.1.1. Publications trend over time

Figure 2 shows the trend in the number of articles published in the field of carsharing. In order not to exclude the early access research articles and reviews, which are not yet assigned a publication year, the early access year of these articles are considered in this figure and also other time-based analyses in this research. The early access articles within our dataset include 21 articles out of which only 1 has an early access year of 2019, 5 has been available online in 2020, and the remaining 15 has a more recent early access year of 2021.

As can be seen in Figure 2, the first article published in WoS in the field of carsharing services dates back to 1980. The number of published articles from 1980 to 2010 remain between 0 and 6 per year but in 2011 this number exceeds double. A continuous growth starts from 2011 (except for 2016) and through an exponential increase, the number of published articles in the year 2020 reached 125. The leap between 2016 and 2017 is also noticeable, which might be due to the massive entry into the market of free-floating services in those years that boosted the number of carsharing subscribers around the world. The number of published articles only in the first half of 2021 (from January 1st to July 1st) was 118, which is expected to lead to a higher record than 2020 by the end of the year. Therefore, this field seems to be still in its expansion period that will probably continue as long as the carsharing services continue their diffusion in different geographical regions beyond the western hemisphere.

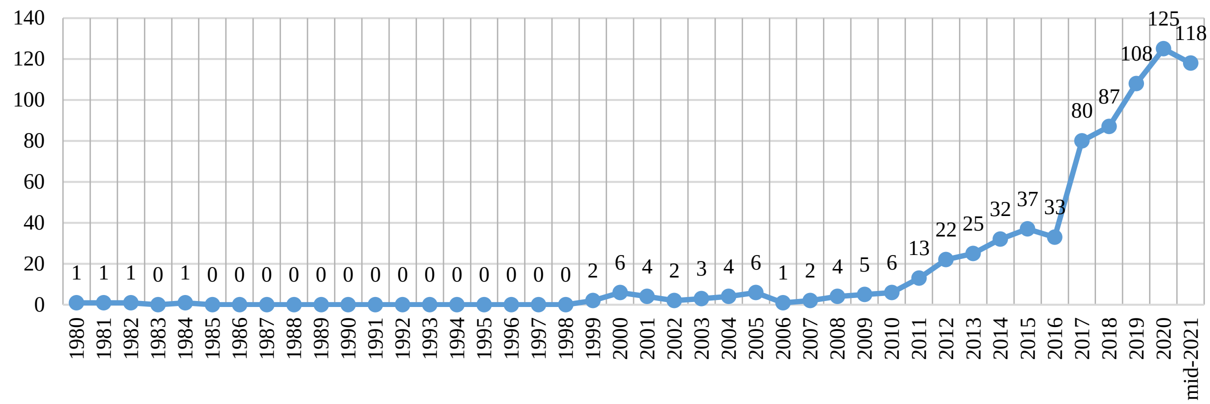


Figure 2. Publication trend in the research field of carsharing.

3.1.2. Leading journals

A total of 255 journals contributed to the publication of the 729 articles in the studied field. It was found that 12 journals, as listed in Table 2, have published at least 10 articles. These journals cooperatively contain 335 papers, representing approximately 45.95% of our sample articles. In addition to the number of carsharing-related articles and their citations in these journals, the share of carsharing articles from the total number of articles published by these journals are reported in Table 2. Since our search was limited to peer-reviewed articles and review papers, this limitation was also considered to extract the total number of articles from WoS for each journal. Furthermore, regardless of the publication year of the first article published by the journals and indexed in WoS, the time horizon for computing the total number of articles was considered to be 1999 (consistent with the main growth of publications in the carsharing field of study as shown in Figure 2) to the end of June, 2021, when the main data for the analyses were taken from WoS. Table 2 also reports the average publication year (APY) of the carsharing-related papers, which indicates a mean of the publication year of the carsharing articles published in the listed journals.

As can be seen in Table 2, out of the presented 12 journals, 10 journals directly focus on the transportation field of study. The other two journals, *Sustainability* and *Journal of Cleaner Production*, focus on environmental studies and green and sustainable science and technology. Also, the share of carsharing-related research from the total number of articles shows that the highest ratio (3.72%) refers to *International Journal of Sustainable Transportation*, whose category (in addition to transportation) is similar to the abovementioned journals. Therefore, this may indicate that a part of attention towards carsharing is highly linked with its sustainability and environmental aspects. Nevertheless, *Journal of Cleaner Production* and *Sustainability* have the lowest share of carsharing-related research from their overall articles published (0.06% and 0.13%, respectively), which highlights the difference between the main focus in these journals and the transport-related ones.

Furthermore, the APY of the articles published by the journals shows that *Transportation Research Record* is older than other journals in terms of the active publication of articles in the field of carsharing (APY of 2013.8 for 45 articles). On the other side of the spectrum, *Journal of Advanced Transportation* (APY of 2019.4 for 15 articles) and *Sustainability* (APY of 2019.3 for 46 articles) are the most recently active journals contributing to the literature on carsharing. Referring to Figure 3, which shows the publication of carsharing research in the considered 12 journals over time, it can be inferred that *Transportation Research Record* has been almost continuously active in the publication of carsharing research since 2007 (except in 2021 that no article in the carsharing field was published in this journal by the end of June). Although the share of carsharing research from the total articles published in this journal is 0.36%, the continuous contribution of this journal in the publication of carsharing research has resulted in the lowest APY (as reported in Table 2) that highlights the role of this journal in research in this field.

Table 2

The list of journals contributing to the carsharing literature with a minimum of 10 published articles.

Journal name	CS* articles	Citations to CS articles	Share of CS articles from the total	APY of CS articles	Publication year of the first article in WoS
Sustainability	46	296	0.13%	2019.3	2011
Transportation Research Record	45	1271	0.36%	2013.8	1998
Transportation Research Part A- Policy and Practice	37	990	1.35%	2016.7	1979
Transportation Research Part D- Transport and Environment	35	653	1.39%	2017.7	1996
Transportation Research Part C- Emerging Technologies	34	1362	1.31%	2017.6	1995
Transport Policy	29	611	1.76%	2017.1	2005
International Journal of Sustainable Transportation	25	639	3.72%	2017.3	2007
Transportation Research Part B- Methodological	24	547	1.11%	2018.2	1979
Transportation	20	548	1.71%	2017.6	1972
Journal of Advanced Transportation	15	62	0.82%	2019.4	1994
Journal of Cleaner Production	15	137	0.06%	2018.6	2002
IEEE Transactions on Intelligent Transportation Systems	10	344	0.29%	2017.5	2000

* Carsharing

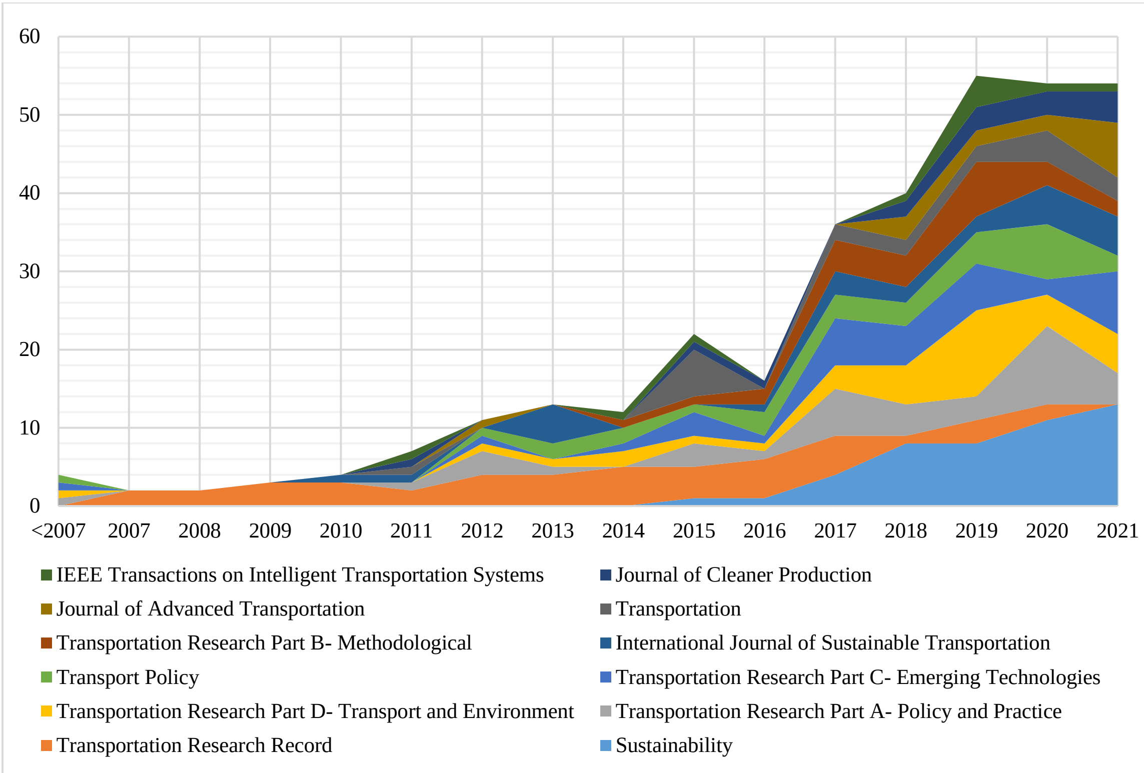


Figure 3. Publication of carsharing research over time in the most contributing journals

3.1.3. Contribution and collaboration of countries

A total of 57 countries contributed to the formation of carsharing literature within the WoS database. Figure 4 illustrated the collaboration network among these countries. The size and color of the frames used for the countries correspond to their number of articles and their APY, respectively. Besides, the availability of a link between two countries indicates their co-authorship and the thickness of the links shows the occurrence of such co-authorship. In order to clarify authorship and co-authorship of the countries, Table 3 provides the list of the top 10 contributing countries in terms of their articles, international collaborators, and collaborations, and Table 4 gives an overview of the most frequent international collaborations among countries. As can be seen in Table 3, the USA is ranked first with regard to all the mentioned 3 rankings, and based on Table 4, its most frequent collaborators are China (23 collaborations), England (9 collaborations), Canada (7 collaborations), and Singapore (6 collaborations). Moreover, Table 5 introduces the most recent and also the oldest contributing countries based on their APY. Based on this table, the Czech Republic, Algeria, Thailand, Egypt, and Slovenia with an APY of 2021 have started their investigations on carsharing very recently. On the other side of the spectrum, Taiwan and the USA have the lowest APY indicating that they have considered this research topic much earlier than the other countries. Since the USA has the highest number of articles and at the same time, is very old in terms of the APY, we can consider this country as a pioneer in terms of research production in the field of carsharing.

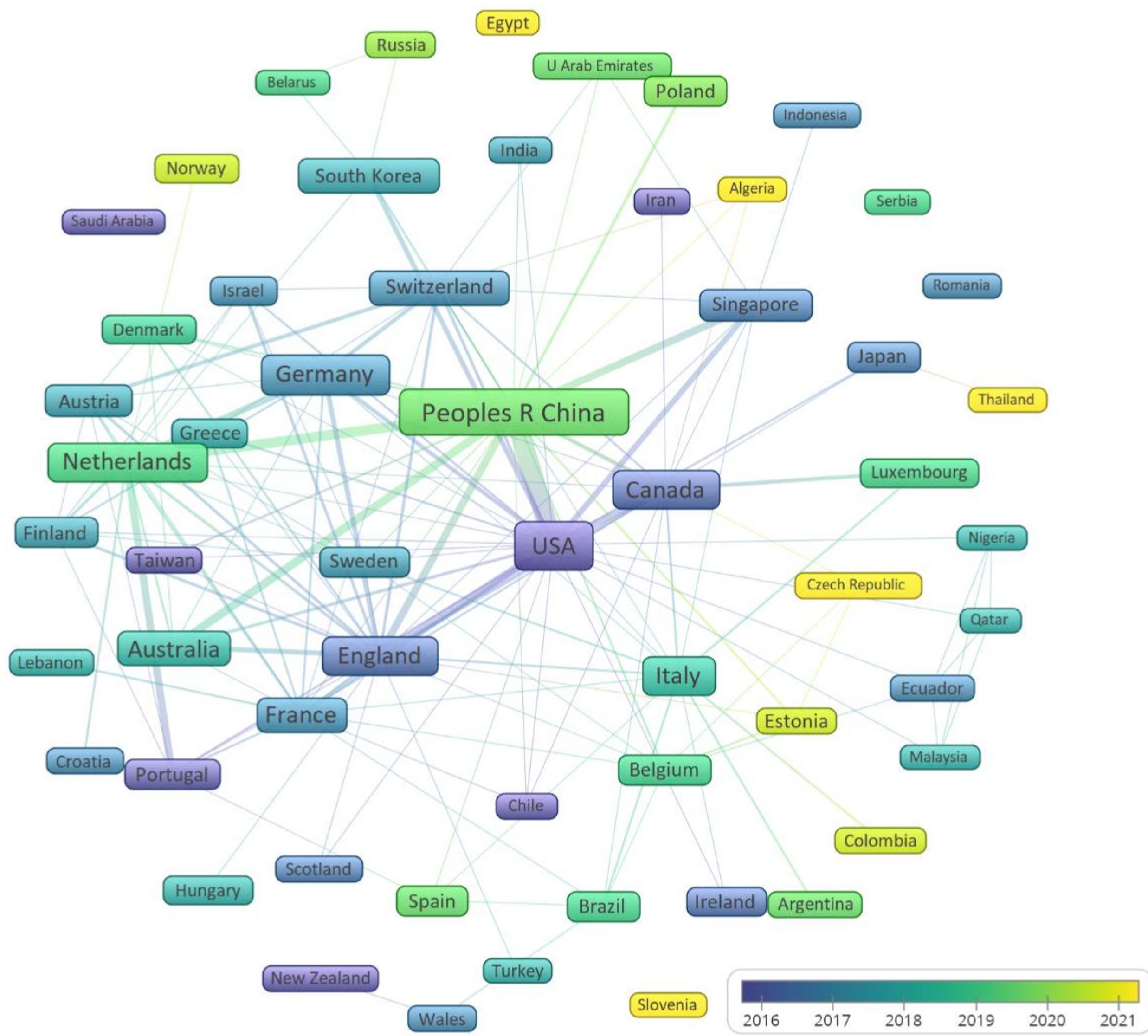


Figure 4. Collaboration network among countries contributing to the carsharing literature

Table 3

List of the top 10 countries contributing to the carsharing research in terms of (a) the number of articles, (b) the number of collaborating partners, and (c) the number of collaborations.

Top 10 contributing countries				Countries with the highest number of collaborating partners			Countries with the highest number of collaborations		
Rank	Country	Articles	Citations	Rank	Country	Collaborating countries	Rank	Country	Collaborations
1	USA	162	6071	1	USA	28	1	USA	87

2	P.R. China	135	937	2	England	23	2	P.R. China	86
3	Germany	77	2004	3	P.R. China	21	3	England	62
4	Canada	58	1637	4	France	16	4	Netherlands	47
5	England	56	1103	5	Canada	15	5	Canada	33
6	Italy	55	656	6	Netherlands	15	6	Germany	31
7	Netherlands	54	662	7	Italy	14	7	France	27
8	Australia	37	434	8	Switzerland	13	8	Switzerland	24
9	South Korea	35	421	9	Germany	12	9	Australia	22
10	Switzerland	32	1090	10	Austria	9	10	Italy	21
	France	32	444		Sweden	9			

Table 4

The most frequent co-authorship among countries in the field of carsharing research.

Collaborating countries		Collaborations
China	USA	23
Netherlands	China	11
Australia	China	9
England	USA	9
England	China	8
Netherlands	Portugal	8
China	Singapore	8
Canada	USA	7
Germany	Netherlands	7
Singapore	USA	6

Table 5

Most recent and oldest contributing countries to the carsharing research based on their average publication year.

Most recent contributing countries				Oldest contributing countries			
Rank	**Country**	**APY**	**Articles**	**Rank**	**Country**	**APY**	**Articles**
1	Czech Republic	2021.0	3	57	Taiwan	2014.3	3
2	Algeria	2021.0	1	56	USA	2015.0	162
3	Thailand	2021.0	1	55	Iran	2015.5	2
4	Egypt	2021.0	1	54	New Zealand	2015.5	2
5	Slovenia	2021.0	1	53	Chile	2015.7	3
6	Estonia	2020.5	2	52	Saudi Arabia	2016.0	1
7	Colombia	2020.5	2	51	Portugal	2016.1	12

8	Norway	2020.4	7	50	Canada	2016.4	58
9	Russia	2020.0	2	49	England	2016.5	56
10	Poland	2019.8	12	48	Ireland	2016.5	8

3.2. Carsharing research hotspots, tendencies, and orientations

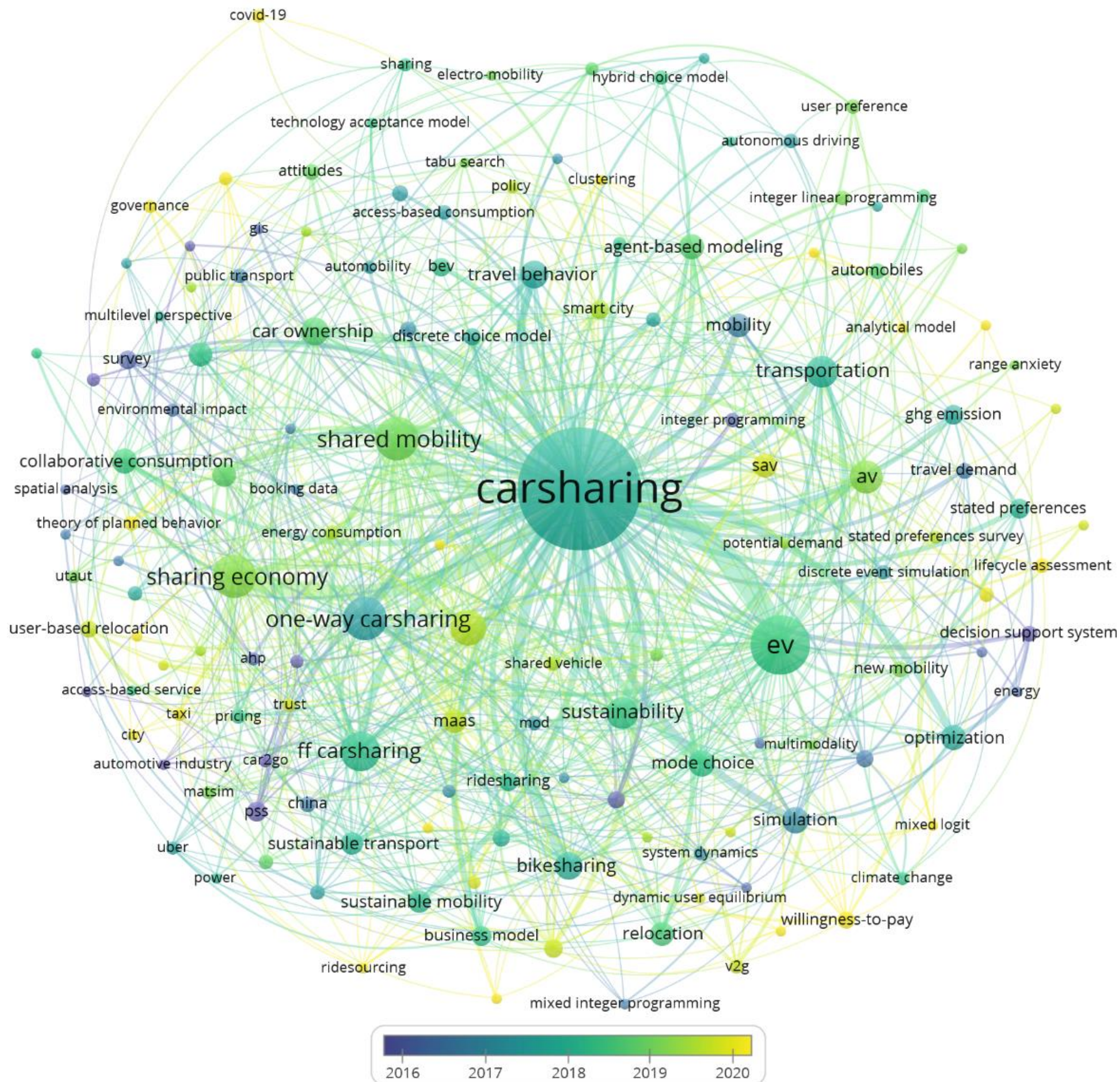
In this section, keyword analysis and also text mining of the title and abstract of the articles were utilized to address the third research question in this study.

RQ3. What are the hotspots and tendencies of carsharing research?

3.2.1. Keyword-based analysis

The concept of carsharing has been referred to in different written forms. The most popular form to address these services is "carsharing", which has been applied in the author keywords of 149 articles within our collection. Other written forms for this term include "car sharing" and "car-sharing", utilized in 107 and 56 articles, respectively. While cleaning the keywords data to prepare it for the analysis, "carsharing" was replaced for the other written form used to address these services. Besides, to estimate the APY of the keywords more precisely, "carsharing services" and "carsharing systems" were replaced with "carsharing".

After the data cleaning and preparation, a total of 1674 unique author keywords were identified, out of which 146 keywords had a minimum of 3 occurrences. Figure 5 illustrates the co-occurrence network built based on these 146 keywords. In this figure, the size of the circles and fonts shows the occurrence of each keyword, while colors are related to the keyword APY. Finally, the thickness of the links between every 2 keywords shows their co-occurrence.



Legend: **AV**: Autonomous vehicle; **EV**: Electric vehicle; **ff carsharing**: Free-floating carsharing; **MaaS**: Mobility as a Service; **SAV**: Shared autonomous vehicle; **PSS**: Product service system; **BEV**: Battery electric vehicle; **MOD**: Mobility on demand; **GIS**: Geographic information system; **UTAUT**: Unified Theory of Acceptance and Use of Technology; **V2G**: Vehicle-to-grid; **AHP**: Analytical hierarchy process; **GHG**: Greenhouse gas.

Figure 5. Co-occurrence network of author keywords within the carsharing research field.

As can be seen in Figure 5, after "carsharing", the keywords "EV", "shared mobility", "one-way carsharing", "sharing economy", and "free-floating carsharing" are the most popular keywords.

Furthermore, "COVID-19" with 4 occurrences is the most recent keyword appearing among the author keywords within the carsharing field of study with an APY of 2021, due to the recentness of the pandemic and the recentness of the studies considering the effect of the pandemic on carsharing services.

A notable point is the appearance of "Uber" among the keywords in Figure 5 with 4 occurrences and an APY of 2017.5. Based on the general specifications of the carsharing services considered in this paper, Uber is not a carsharing but a ride-hailing platform. However, Yun et al. (2020) regarded Uber as a short-distance carpooling platform whose business model falls under one of the various categories of car-sharing business models and therefore, considered Uber as a carsharing platform. Obtaining a similar approach, Sun et al. (2018) considered Uber as a carsharing platform with a carpool application. Santos (2018) and Cohen and Kietzmann (2014) pointed to Uber while discussing various shared mobility business models and therefore, Uber was noted in their keywords.

Table 6 provides more details on the occurrences and APY for some selected keywords from Figure 5. A comparison of the APYs of various forms of carsharing in Table 7 shows that on average, P2P carsharing (2018.8) is more recently focused on by the researchers, followed by free-floating carsharing (2018.1), one-way carsharing (2017.4), and round-trip carsharing (2016.7), respectively.

Table 6

Occurrence and average publication year of selected author keywords within the carsharing research field.

Keyword	Occurrence	APY	Keyword	Occurrence	APY
Carsharing	342	2017.8	Carpooling	5	2017.6
EV – Electric vehicle	81	2018.4	Energy consumption	5	2019.4
Shared mobility	45	2018.9	Lifecycle assessment	5	2020.4

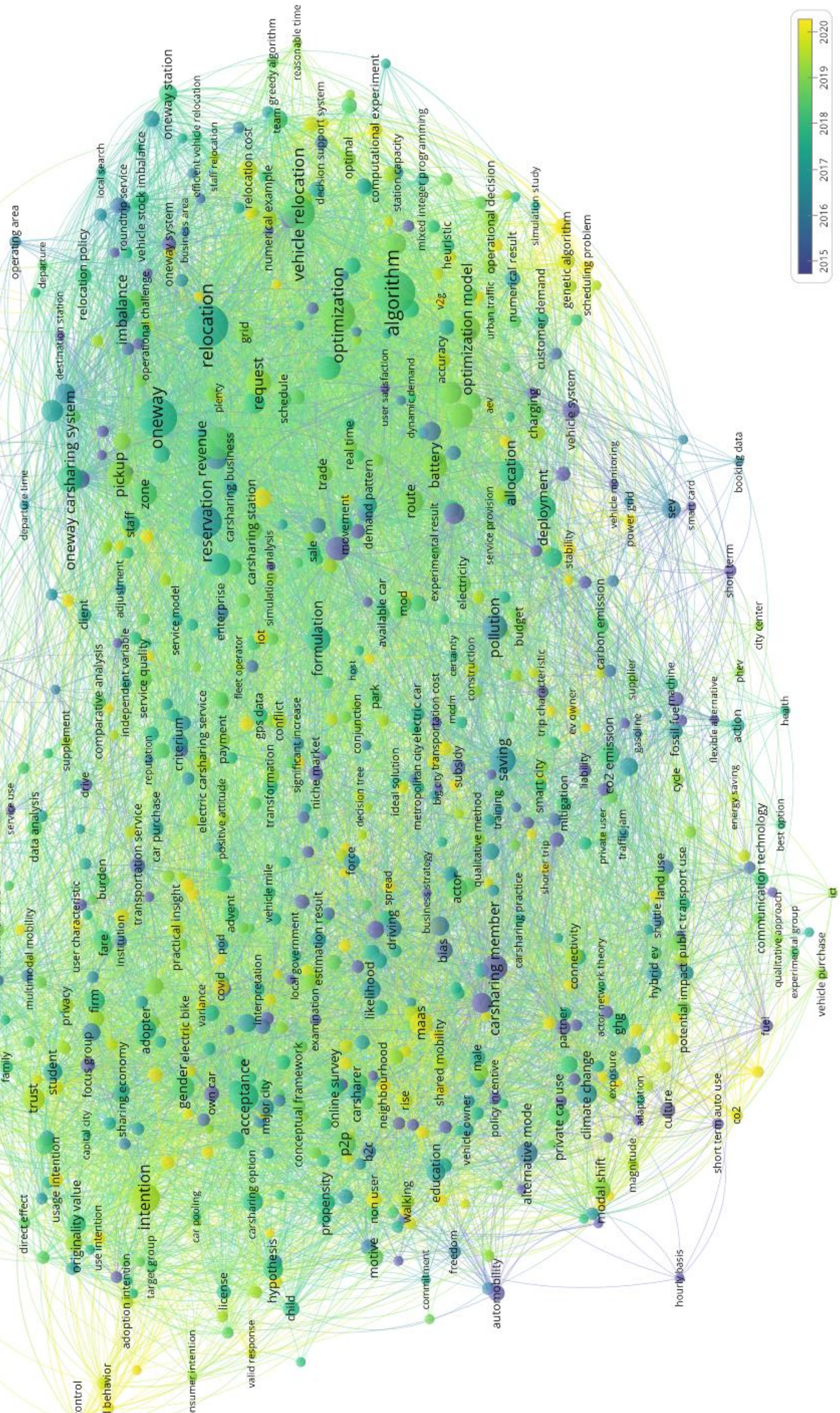
One-way carsharing	44	2017.4	MOD – Mobility on demand	5	2017.2
Free-floating carsharing	37	2018.1	Climate change	4	2018.3
E-carsharing	29	2019.4	Fleet size	4	2018.3
Car ownership	18	2018.7	Sustainable consumption	4	2015.5
MaaS – Mobility as a service	13	2019.5	Access-based service	3	2018.3
P2P – Peer-to-peer carsharing	13	2018.8	Range anxiety	3	2019
SAV – Shared autonomous vehicles	13	2019.7	Ride sourcing	3	2020.3
Smart city	8	2019.4	Round-trip carsharing	3	2016.7

3.2.2. Text mining analysis

Through using the text mining function of VOSviewer for our corpus of documents, a list of 14,725 noun phrases was identified as the potential terms describing the research topics and themes of the carsharing field. To capture the terms that are sufficiently frequent to be potential descriptors of our considered subject area, the terms with a minimum of 3 occurrences based on a binary counting method (in which counting is based on the presence or absence of a term, not all the occurrences of a term within a single article) were considered for further analysis, leading to a list of 1,598 terms. Furthermore, according to Van Eck and Waltman (2011), to remove general terms such as paper, approach, and article, which fail to describe a specific topic, only the 60% most relevant terms based on the statistical method applied in the software were considered, resulting in a list of 959 terms. We additionally checked the obtained list thoroughly and removed the remaining irrelevant terms such as the name of the cities and countries. Finally, 754 terms remained for further analysis.

Figure 6 illustrates the time overlay of the terms extracted from titles and abstracts of our corpus of articles. The range of colors in this figure refers to the recentness of the APY of the identified terms. Besides, similar to Figure 5, the fonts and size of the circles in Figure 6 reflect the occurrence of the terms. As it can be seen, the nouns ‘algorithm’, ‘relocation’, and ‘one-way’ with 54, 51, and 44 occurrences are the identified most frequent terms in this figure, showing the research tendency towards optimization problems and algorithms in the field of carsharing.

However, focusing on the APY of the terms may indicate the most recent subjects and concerns addressed by the researchers, regardless of the occurrence of the terms. In contrast with the terms ‘smart card’ and ‘private automobile’ that have the lowest APYs (2001.3 and 2002, respectively), ‘power grid’ and ‘mobile device’ with 4 and 3 occurrences, respectively, are the two most recent terms with an APY of 2021. Although these recently noticed terms in carsharing-related articles have a low occurrence in our database, their APY shows that the articles using these terms have been published in 2021, and therefore, these terms address a very recent concern. The third most recent term is ‘COVID-19’ with an APY of 2020.9 and 8 occurrences, pointing to the effects of the recent pandemic addressed by the researchers in the carsharing-related articles.



2015
2016
2017
2018
2019
2020
oneway station
vehicle relocation
algorithm
optimization
relocation
oneway
oneway carsharing system
reservation
revenue
request
imbalance
pickup
zone
staff
optimization model
battery
allocation
deployment
charging
vehicle system
sev
route
trade
movement
demand pattern
formulation
pollution
saving
co2 emission
carbon emission
fossil fuel
carsharing member
acceptance
intention
trust
adopter
gender
maas
p2p
propensity
hypothesis
motive
automobility
alternative mode
private car use
climate change
modal shift
culture
fuel
communication technology
potential impact
public transport use
shuttle
land use
hybrid ev
ghg
likelihood
criterion
payment
enterprise
carsharing station
carsharing business
genetic algorithm
scheduling problem
numerical result
customer demand
operational decision
heuristic
computational experiment
decision support system
numerical example
relocation cost
vehicle stock imbalance
roundtrip service
relocation policy
destination station
operating area
pickup demand
trip end
booking data
short term
city center
health
vehicle purchase
ict
co2
short term auto use
hourly basis
behavioral control
planned behavior
adoption intention
consumer intention
valid response
college student
performance expectancy
unified theory
service attribute
social influence
potential demand
demand model
data analysis
latent variable
multimodal mobility
user characteristic
focus group
student
sharing economy
usage intention
originality value
use intention
target group
license
child
freedom
commitment
walking
education
non user
online survey
carsharer
neighbourhood
shared mobility
male
vehicle owner
policy incentive
partner
connectivity
bias
actor
driving spread
niche market
transformation
conflict
gps data
iot
smart city
mitigation
subsidy

380

Legend: **IoT**: Internet of things; **ICT**: Information and communications technology; **P2P**: Peer-to-peer; **B2C**: Business-to-consumer; **EV**: Electric vehicle; **SEV**: shared electric vehicle; **MaaS**: Mobility as a Service; **SAV**: Shared autonomous vehicle; **SAEV**: Shared autonomous electric vehicle; **MOD**: Mobility on demand; **V2G**: Vehicle-to-grid; **GHG**: Greenhouse gas.

Figure 6. Co-occurrence network and time overlay (average publication year) of the identified terms through text mining of the titles and abstracts of the articles within the carsharing research field

To show the general research tendencies in the considered study area, Figure 7 presents the timeline of the selected terms that were identified from the text mining of titles and abstracts. APYs of the terms shown in this figure indicate that urban planning (APY: 2019), urban traffic (APY: 2018.7), land use (APY: 2018.8), and infrastructure planning (APY: 2020.2) have attracted the attention of researchers in the field of carsharing. Studies on carsharing services also point to other shared mobility services, including electric bikes (APY: 2019.5) and scooter sharing (APY: 2020.3), and address the planning for smart mobility (APY: 2019.3) services for a transition towards sustainable transportation in 2020 and 2021 more than before. Furthermore, fuel consumption in carsharing systems is not a recent concern (APY: 2015.5), GHG emissions and pollution have been extensively addressed by researchers in this area (APY: 2017-2019), and carsharing has been considered as a part of a sustainable transport system (APY: 2017.8) since many years ago. Nevertheless, in terms of the electrification of carsharing systems, the relevant power grid (APY: 2021) structure and the recent technologies such as V2G – vehicle-to-grid (APY: 2020.7) that provides the opportunity for selling the extra energy of electric shared vehicles to a power grid (He and Yamamoto, 2020) have recently been the focus of researchers. Therefore, carsharing-related studies seem to be getting far from the market-related studies (e.g. market potential (APY: 2010.6) and business-to-consumer (APY: 2015.8)) and generally, have a stronger tendency towards more technological advancements and building more sustainable and smart cities.

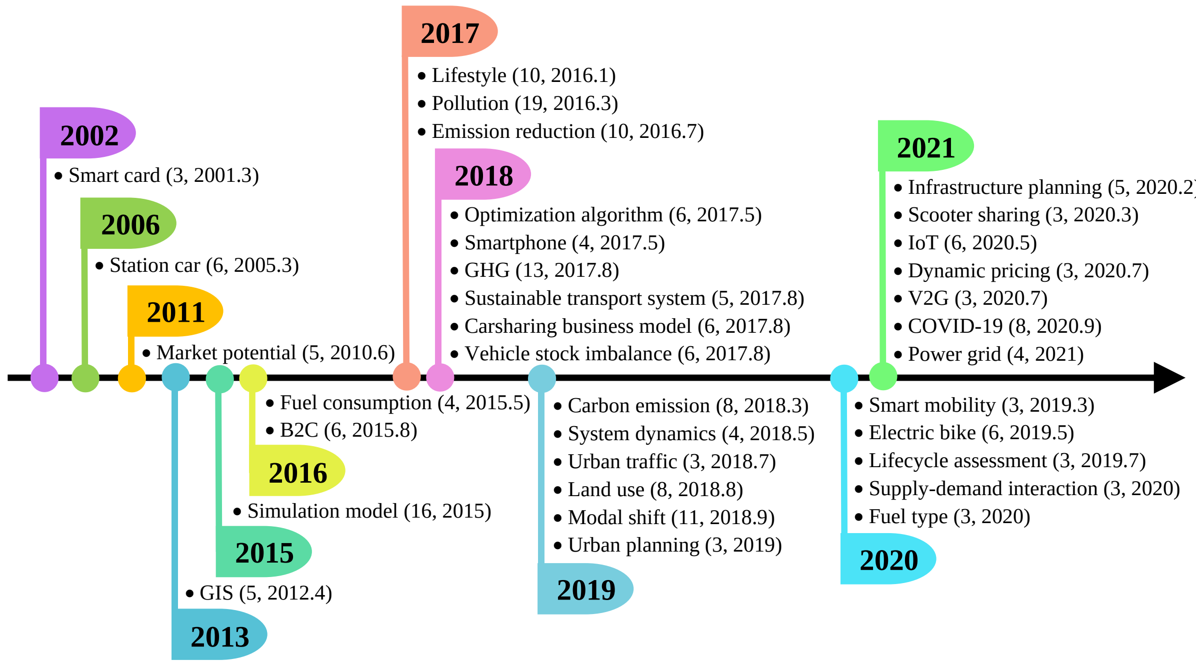


Figure 7. Timeline of the hotspots and research tendencies within carsharing study area extracted from title and abstract of the articles (occurrences and average publication year in parentheses)

3.3. Bibliographic coupling analysis: Discovering major emergent carsharing research themes

The findings of this section address the third RQ of this study:

RQ3. What are the major research themes building carsharing literature?

The article clustering technique based on bibliographic coupling links among the articles was used. Table 8 provides the details of the carsharing research clusters in terms of the number of articles and APY. In this regard, two points were considered in constructing the bibliometric network. Firstly, review papers (N=24) were excluded from the articles (N= 729) in this stage due to their high link strength, which may make the clustering results biased. In bibliographic coupling networks, the link strength between two documents refers to the number of references they have in common. The more references they have in common, the higher the link strength is. Secondly, among the remained 705 articles, 19 articles that did not have a common reference with others were also excluded from the data. Consequently, the bibliographic coupling network was constructed including a total of 686 articles in the carsharing literature.

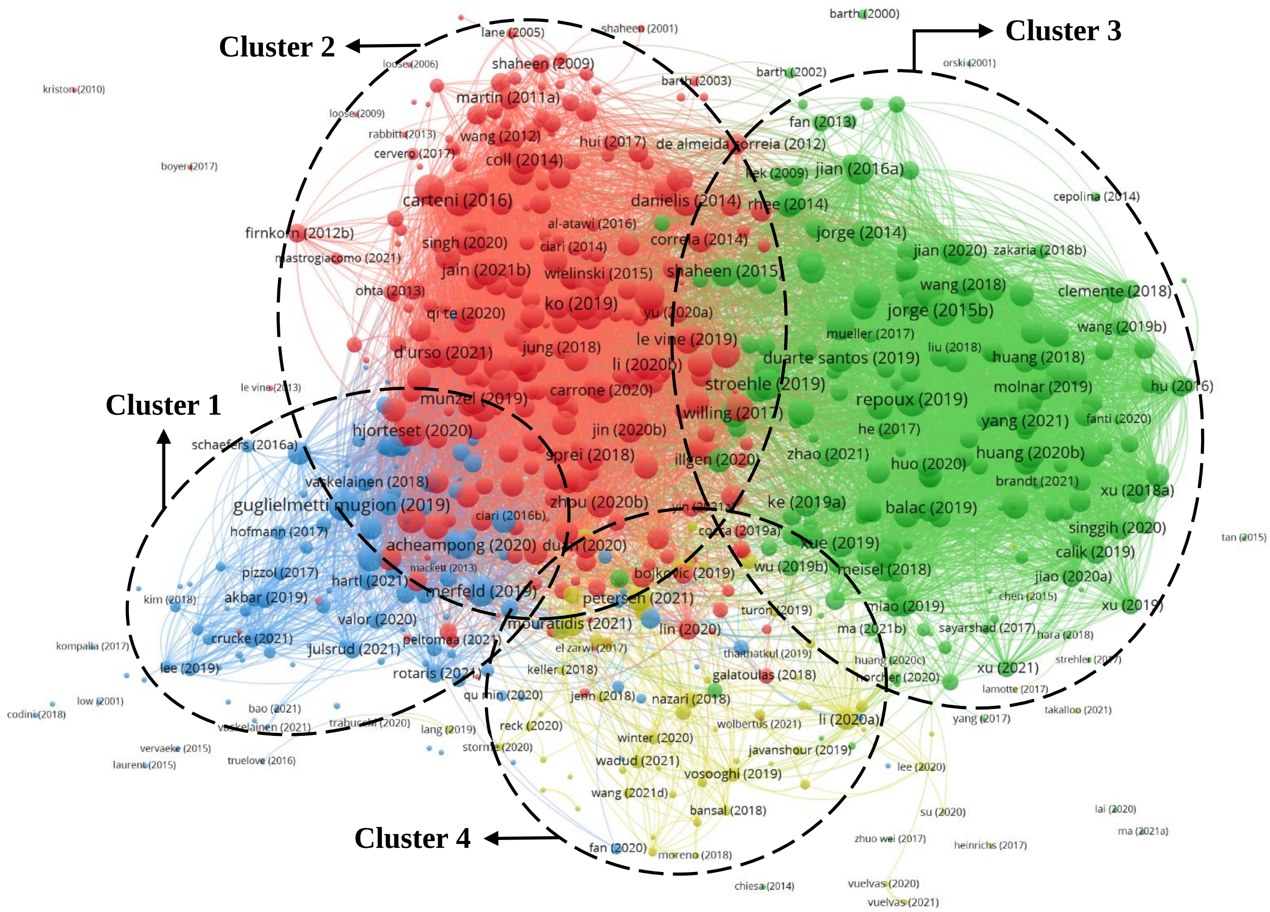
Table 8

Bibliographic coupling clusters details.

Cluster	Number of items	APY	Sample references
Cluster 1: Collaborative consumption and carsharing business models development in the context of sustainable urban transport	127	2017.8	Hartl et al. (2018), Münzel et al. (2018), Rotaris (2021), Vaskelainen and Münzel (2018), Novikova (2017), Hartl and Hofmann (2021), Bocken et al. (2020), Diao et al. (2021)
Cluster 2: Carsharing adoption: User behavior, intention, and preferences	285	2015.9	Matowicki et al. (2021), Hjorteset and Böcker (2020), Le Vine and Polak (2019), Ko et al. (2019), Kim et al. (2019), Chen and Kockelman (2016), Jin et al. (2020), Diana and Ceccato (2019), Ramos et al. (2020)
Cluster 3: Carsharing operational challenges: Infrastructure and fleet management	198	2017.7	Zhao et al. (2021), Zhang et al. (2020), Huang et al. (2020), Martínez et al. (2017), Correia and Antunes (2012), Illgen and Höck (2018), Repoux et al. (2019)

Cluster 4: Technological advancement towards deployment of shared autonomous vehicles and MaaS	76	2019.0	Vosooghi et al. (2020), Chen et al. (2016), Li and Liao (2020), Reck and Axhausen (2020), Storme et al. (2020), Wadud and Chintakayala (2021), Haboucha et al. (2017)

As a result, the analysis revealed four main emergent research themes of the carsharing literature as follows: (i) collaborative consumption and carsharing business models development in the context of sustainable urban transport, (ii) carsharing adoption: user behavior, intention, and preferences, (iii) carsharing operational challenges: infrastructure and fleet management, and (iv) technological advancement towards deployment of shared autonomous vehicles and MaaS. The bibliographic network of the clustered articles is visualized in Figure 8. In this Figure, nodes represent the articles, and their size and font show their total link strength. Therefore, larger nodes represent articles that share more references with other articles.



	Cluster 1	Collaborative consumption and carsharing business models development in the context of sustainable urban transport
	Cluster 2	Carsharing adoption: User behavior, intention, and preferences
	Cluster 3	Carsharing operational challenges: Infrastructure and fleet management
	Cluster 4	Technological advancement towards deployment of shared autonomous vehicles and MaaS

Figure 8. Bibliographic coupling network of the carsharing research.

3.3.1. Cluster 1: Collaborative consumption and carsharing business models development in the context of sustainable urban transport

Collaborative consumption refers to the P2P-based activities of obtaining, giving, or sharing the access to goods and services enabled by information and communication technologies (Hamari et al., 2016). One of the most widespread applications of the concept of collaborative consumption, as a core of the sharing economy, has emerged in the mobility sector through providing carsharing services (Novikova, 2017). Carsharing services based on collaborative consumption have been increasingly developed as a promising solution for sustainable transportation (Hartl and Hofmann, 2021) to enhance accessibility and reduce the negative externalities produced by the transport sector (Rotaris, 2021).

The basic carsharing business model was introduced by local entrepreneurs, often not-for-profit initiatives, and then was developed through regional replication and mimicry processes (Schaltegger et al., 2016). In this regard, the value proposition and delivery of carsharing services have been evolved from station-based business models (i.e., cars should be picked up and dropped off only at specific stations) to free-floating carsharing systems (i.e., cars could be picked up and dropped off at any place within a specific operational area), which deliver a different value proposition for users (Schaltegger et al., 2016). Carsharing operators provide services, as an alternative to private car ownership, through different ownership structures and business models (Münzel et al., 2018).

In this regard, various business model types have been characterized by scholars within the literature. For instance, Münzel et al. (2018) highlighted four different business models for carsharing services, including (i) cooperative with a not-for-profit orientation and interest for sharing vehicles, (ii and iii) B2C divided into roundtrip and one-way models, which refers to a company owning a fleet of cars to rent them on-demand for a temporarily use, and (iv) P2P carsharing that addresses sharing cars between individuals with the help of a company as a mediating platform, mainly enabled by using online platforms. Most notably, P2P carsharing, as a socio-technical innovation, has gained momentum intending to support a transition from the traditional to a more sustainable urban mobility system (Valor, 2020).

According to Yun et al. (2020), the idea of promoting carsharing services until 2000 was mainly focused on addressing environmental concerns, such as emission reduction through decreasing car ownership and providing eco-efficient services. However, professional carsharing development by environmentally concerned citizens shifted to market expansion through user-led innovation processes (Truffer, 2003) and technologies, such as relocation algorithms for free-floating car-sharing systems (Weikl and Bogenberger, 2013; Yun et al., 2020). Research has shown that personal car-based mobility in cities is losing its share of urban travels by entering new mobility business models such as carsharing, which delivers functionality rather than ownership (Bocken et al., 2020, 2014; Kent and Dowling, 2013). In their research on the implications of the sharing economy for transport, Standing et al. (2018) highlighted the trend to avoid assets ownership, trust, and using online platforms as facilitating factors of the growth of sharing economy and collaborative consumption in transport. In this regard, member-to-vehicle ratios, market segments, parking approaches, technology, insurance, and vehicle and fuel variety have been highlighted in the literature as the key factors characterizing carsharing operations growth in the carsharing market (Perboli et al., 2018; Ranjbari et al., 2019; Shaheen and Cohen, 2007).

The research in this cluster has been mainly focused on issues regarding developing carsharing services within cities, such as proposing innovative subsidy models (Fan et al., 2020), sharing and trust in online environments (Julsrud and Priya Uteng, 2021), social capital, and value co-creation (Hartl and Hofmann, 2021; Tchorek et al., 2020), carsharing business models diffusion

(Münzel et al., 2018), the effects of institutional logics on the carsharing business model development (Vaskelainen and Münzel, 2018), carsharing business models and tariff simulation (Perboli et al., 2018), and upscaling strategies for carsharing business models (Meijer et al., 2019). Besides, some articles in this cluster address the environmental impacts of carsharing (Shams Esfandabadi et al., 2020) and its sustainability (Akyelken et al., 2018; Bocken et al., 2020; Hartl et al., 2018), since carsharing is a promising idea towards transportation sustainability especially when electric vehicles (EVs) are utilized to provide carsharing services (Kot, 2020). Shams Esfandabadi et al. (2020) pointed to the circular economy approach in the development of carsharing services and highlighted the role of car manufacturers, regulators, and service providers in the organization of carsharing platforms and services. In this vein, they highlighted the effect of positive and negative effects of carsharing on the pollution of air, water, and soil. Nevertheless, Hartl et al. (2018) showed that the sustainable impact of carsharing is perceived by the users as a positive side effect rather than a main argument; and environmental concerns become important for carsharing users when they decide to use P2P over B2C services.

However, despite the potential benefits of developing carsharing platforms as a solution for sustainable mobility, its role in supporting urban mobility sustainability is still unclear and under intense debate. For instance, Diao et al. (2021) showed that promoting large-scale carsharing platforms and transportation network companies in the United States have intensified urban transport challenges, such as increased road congestion in terms of both intensity (by 0.9%) and duration (by 4.5%). In another research, Boons and Bocken (2018) outlined the potential of expanding carsharing services to increase car dependency. Taken together, the actual role of existing shared mobility services within the whole transportation system in the path towards sustainability of the urban mobility system needs more critical research and investigative explorations. It is likely that the above-mentioned different carsharing schemes have a diversified impact in terms of environmental sustainability.

3.3.2. Cluster 2: Carsharing adoption: User behavior, intention, and preferences

Potential users of carsharing constitute the demand side of the market for these services. Therefore, efficient planning by carsharing service providers for a profitable business requires adequate knowledge about the users' behavior, intention, and preferences. On the other hand, understanding the implications of carsharing adoption for car ownership, using other transport modes, and the environment are crucial for decision-makers in urban planning, as well as the service providers who need to strengthen their marketing programs. Therefore, carsharing use intention, switching intention among various travel modes, and the outcomes of using carsharing services have been widely discussed in the carsharing literature.

Studies have pointed to different socio-demographic, socio-economic, and attitudinal variables affecting the utilization of carsharing by commuters in different regions and cities. Research conducted by Burghard and Dütschke (2019) in Germany, Matowicki et al. (2021) in the Czech Republic, Hjorteset and Böcker (2020) in Norway, Ramos et al. (2020) in Italian and Swedish cities, Kim et al. (2017) in the Netherlands, and Li and Kamargianni (2019) in China are a few examples in this regard. Furthermore, Bulteau et al. (2019) explored a comprehensive set of socio-demographic and socio-economic, interpersonal, and contextual variables in Paris to analyze the possibility of the carpooling and carsharing implementation in this region. Prieto et al. (Prieto et al., 2017) studied the socio-demographic drivers of the intention to adopt carsharing in London, Madrid, Paris, and Tokyo, and concluded that the probability of carsharing adoption is significantly higher among those who live in the city center, who are male, and who are highly educated. Similarly, Ceccato and Diana (2018) found that young males living in low-size and high-income households with many workers and few cars constitute the main share of carsharing members in Turin, Italy.The majority of studies concerning the switching intention among various transport modes, and more specifically switching towards and from carsharing, have implications both for service providers and the authorities, the latter with a more emphasis. Based on the obtained data from two surveys in Turin, Ceccato et al. (2021) highlighted that the willingness to switch towards new transport modes is stronger for people with multimodal travel habits. Also, Diana and Ceccato (2019) found that both personal car drivers and public transport users are willing to walk up to five minutes to reach a shared car; and in contrast with a majority of the personal car drivers, public transport users are more likely to switch to carsharing if the cost of these services is lower. Therefore, they called for more attention by the decision-makers and authorities to increase the attractiveness of public transport with respect to carsharing to avoid switches from public transport.

Besides, in a stated-preference mode choice analysis in Beijing, China, it was shown that if shared electric vehicles (SEVs) are incorporated into an urban transport system, they are more favorable for leisure trips than commuting ones and can be replaced for taxis in long-distance trips (Jin et al., 2020). Furthermore, Münzel et al. (2019) targeted B2C and P2P carsharing adopters in the Netherlands and considering variables reflecting motivations and obstacles for the attitude towards carsharing usage, highlighted the importance of forming a connected multi-modal transportation system by the regulators instead of setting separate regulations for each carsharing business model. In addition to the switching intention among various transport modes, several papers discuss the relationship between carsharing adoption and car ownership (e.g. Le

Vine and Polak (2019), Ko et al. (2019), and Kim et al. (2019)), whose major audience includes authorities and policy-makers.

Moreover, the adoption of carsharing services has resulted in different environmental outcomes, which should be carefully considered by the authorities and regulators. On the one hand, the reduction of the number of the required passenger cars to satisfy the mobility demand and the substitution of more fuel-efficient shared vehicles for private vehicles use result in the reduction of GHG emissions; and on the other hand, attracting car-less commuters towards using carsharing leads to increasing GHG emissions (Jung and Koo, 2018). For instance, a study conducted by Namazu and Dowlatabadi (2015) showed that using a newer and optimized carsharing fleet in a Canadian context can potentially reduce the GHG emission by more than 30% regardless of modal shifts. Furthermore, despite a large growth potential for carsharing market share in Turin (Ceccato and Diana, 2018), Chicco and Diana (2021) found that the carsharing modal share in this Italian city might grow up to a maximum of 10% out of all trips made by any means, for all distances, by the city population aged 18 or more; nevertheless, potential environmental benefits from this growth are partially offset due to the switches from public transport and active modes to carsharing services. Chen and Kockelman (2016) analyzed the lifecycle impacts of carsharing on energy consumption and GHG emissions in the USA and concluded that net savings resulting from the adoption of carsharing are expected to be 5% across all households. Based on their research, modal shift, avoided travel, fuel consumption, and savings in parking infrastructure demands result in 5% savings in all household transport-related energy use and GHG emissions; however, since a part of this saving is then spent on other goods and services, the net savings across all households in the USA would be 3%. Therefore, more comprehensive studies are encouraged to be conducted by researchers in this regard to better help regulators and policy-makers in their decision-making processes regarding carsharing development.

3.3.3. Cluster 3: Carsharing operational challenges: Infrastructure and fleet management

Fleet management operations and optimal design and location of facilities are the prominent challenges at the operational level of carsharing services, which are addressed by the articles in this cluster. These challenges are the main objectives for optimization and simulation in carsharing systems (Ferrero et al., 2018) and therefore, major methodological approaches of the articles in this cluster are based on optimization, simulation, or a combination of both.

Research shows that depot locations can affect the usage of carsharing services (Jian et al., 2016). Therefore, deciding on the optimal location of the shared vehicle depots plays a key role in the profitability of carsharing service providers (Correia and Antunes, 2012). Incorporating EVs into carsharing programs adds to the importance of the optimal location of the depots and charging stations because of the limited driving range and low charging speed of EVs, which are considered as discouragements for their broad adoption (Hu et al., 2019). Moving towards the decarbonization of transportation, as a leading contributor to the emission of GHGs, draws more attention towards the diffusion of alternative-fuel vehicles, such as EVs (Keith et al., 2020); and therefore, shared EVs have been the focus of many researchers in the field of carsharing. As a result, in line with the timeline presented in Figure 7, the challenges with the state-of-charge (SOC) of EVs and the possible opportunities regarding the vehicle-to-grid (V2G) electricity selling in EV sharing have been the subject of recent studies in the field of carsharing research. Kahlen et al. (2018) focused on the virtual power plants (VPPs) potentials in balancing the electricity smart grids and analyzed the exchange of electricity between EVs and the grid, addressing the demand patterns of electric carsharing vehicles. The simulation-based optimization model developed by Zhao et al. (2021) to address a system infrastructure design problem for an electric autonomous vehicle sharing, the optimization model proposed by Zhang et al. (2020) to investigate the benefits of integrating V2G in electric carsharing, and the discrete event simulation model presented by Illgen and Höck (2018) to examine the operation of EVs in carsharing networks are some other examples.

Efficient fleet rebalancing through the relocation of shared vehicles to balance supply and demand is a challenge for service providers, both in one-way (Yang et al., 2021) and free-floating (Willing et al., 2017) carsharing services. To conquer the imbalanced distribution of vehicles' supply, user-based (Di Febbraro et al., 2019), operator-based (Santos and de Almeida Correia, 2019), or a combination of user-based and operator-based relocation strategies can be applied (Huang et al., 2020). Each of these strategies entails several challenges, and the replacement of combustion engine vehicles with EVs adds more operational challenges due to the range limitation of EV batteries. For instance, aiming at the maximization of the carsharing service provider's profit, Huang et al. (2020) compared the efficiency of a user-based and an operator-based relocation system in a one-way electric carsharing platform through the development of three mixed integer nonlinear programming models, taking SOC of EVs into account. Di Febbraro et al. (2019) proposed a two-stage optimization model to optimize the alternative destinations suggested to users and also to maximize the operator's profit in a one-way carsharing system with a user-based relocation strategy. A bilevel nonlinear mathematical programming model, considering the vehicle fleet, prices, relocation operations, and the choice of travelers between carsharing and private cars, was proposed by Lu et al. (2021) to maximize the carsharing service provider’s profit and minimize the overall travel cost for travelers. Furthermore, a proactive operator-based relocation policy based on Markov chain dynamics was introduced by Repoux et al. (2019), which applies reservation information for the prediction of stations' future states and aims to maximize the number of accepted user requests.

In addition to the optimization models, simulations have been considered by researchers to incorporate their analysis in a realistic operational environment. For instance, Boyacı et al. (2017) developed an integrated multi-objective mixed-integer linear programming optimization and discrete event simulation framework to deal with the operational decisions of vehicle and personnel relocation in a carsharing platform, which allows reservation by users in advance. Also, an agent-based model was developed and applied to the city of Lison by Martínez et al. (2017), considering the complex supply-demand relationship, maintenance operations, relocations, and reservations. The supply-demand imbalance has also been analyzed through other methodological approaches, too. In this regard, Willing et al. (2017) developed a spatial decision support system based on data from a carsharing service provider in Amsterdam, which contributes to lowering the risk of supply-demand imbalance in free-floating carsharing systems through variable trip pricing.

In addition to the vast amount of research regarding fleet management and infrastructure in this cluster, other challenges such as the competition among carsharing operators (Balac et al., 2019) and the effect of carsharing on the market and the number of vehicles (Ke et al., 2019) have also been addressed in optimization and simulation models in the articles. Balac et al. (2019) investigated the competition of two free-floating carsharing companies by analyzing the impact of different price levels and performing relocations in an agent-based simulation environment.

The growth strategies in carsharing networks were evaluated by Fassi et al. (2012) through a discrete-event simulation model considering the maximization of the carsharing members' satisfaction level and the minimization of the number of shared vehicles used. Nevertheless, the main focus of the research gathered in this cluster is the concerns at the operational level of carsharing activities.

3.3.4. Cluster 4: Technological advancement towards deployment of shared autonomous vehicles and MaaS

Vehicle sharing, electrification, and automation are three revolutions (so-called "3-R") on track in urban transportation (Fulton, 2018). Although the earliest carsharing experiences date back to more than seven decades ago (Shaheen et al., 1998), these services are still an emerging phenomenon (Münzel et al., 2018) and represent a small share of trips only in some urban areas (Fulton, 2018). Given the growing attention of policy-makers to shifting towards electric and green transportation to respect the environment (e.g. EC (2009) and EC (2014)) and the recent advances in EVs' battery technologies, incorporating EVs into carsharing programs and providing electric carsharing services has been expanded quickly around the world but it has not yet become mainstream (Hu et al., 2019). Moreover, full automation of vehicles is the next major evolution in urban mobility and autonomous vehicles (AVs) (also called driverless or self-driving vehicles) are anticipated to bring fundamental shifts in urban transportation systems (Mourad et al., 2019). The arrival of AVs on the one hand is argued to make driving cheaper, safer, faster, and greener, reducing traffic congestion and environmental impacts reduced; and on the other hand, is increasing concerns on inducing addition driving that can result in offsetting or overwhelming the positive effects (Naumov et al., 2020). Although AVs are still being tested, they are expected to be an integral part of future transportation within the next few decades (Vosooghi et al., 2020) and serve as shared autonomous vehicles (SAVs) within the carsharing scheme. Future SAVs are likely to be electric (Vosooghi et al., 2020; Zhao et al., 2021) and hence, these emerging technological advances can help make the carsharing systems more efficient and environmental-friendly.

Several recent studies have focused on the development of AVs, SAVs, and shared autonomous electric vehicles (SAEVs) and have analyzed their relevant implications. For instance, Zhao et al. (2021) provided an optimization model for a near-optimal design of charging station location of SAEVs; Chen et al. (2016) suggested a simulation model to examine the operation of SAEVs under various vehicle and infrastructure scenarios; and Vosooghi et al. (2020) investigated the impact of charging infrastructure on the performance of SAEVs. Also, Li and Liao (2020) developed an optimization model to moderate the supply and demand of SAVs. Another group of researchers, such as Wadud and Chintakayala (2021), Haboucha et al. (2017), and Nazari et al. (2018), considered user preferences and the willingness to own an AV or use an SAV.

However, technological advancements linked with carsharing in the urban transportation system are not limited to the electrification and automation of vehicles. Mobility as a service (MaaS) is an emerging concept in this regard, which aims at breaking the determining role of car ownership (Becker et al., 2020) by matching the travel needs of an individual with a tailored mobility package (Storme et al., 2020) that includes various mobility services such as carsharing, ride sharing, bike sharing, car rental, taxi services, and public transport. MaaS integrates payment and routing across several transport service providers on a single platform (Reck and Axhausen, 2020) and includes a real-time journey planner (Storme et al., 2020). Although this digital interface increases the efficiency of passenger transportation networks (Esztergár-Kiss and Kerényi, 2020), it is suggested that it should be regarded as a complement of private car use rather than a substitution for it (Storme et al., 2020). Despite considering carsharing as a model of transport in some recent studies on developing MaaS (e.g. Esztergár-Kiss and Kerényi (2020), Brezovec and Hampl (2021), and Reck and Axhausen (2020)), research on MaaS plans is still in its infancy and needs to receive more attention from the researchers in the field of shared mobility.

4. Implications for research: Directions for future studies

Based on the inclusive map of carsharing research provided in previous sections, the potential directions for further research in the future are presented in this section to address the last RQ of this study:

RQ4. What are the potential directions for future research on carsharing services?

Having scrutinized the main research themes and trends, hotspots, and theoretical and practical contributions of existing studies within the carsharing literature so far, five main research gaps, as potential directions for future research, were identified as follows.

4.1. Developing a long-term sustainability assessment framework

The actual impact of the entrance of shared-mobility service providers, such as carsharing platforms, to the market on transitioning towards sustainability is still under discourse. On the one hand, carsharing can provide benefits, such as lower individual transportation energy use and greenhouse gas emissions (Chen and Kockelman, 2016; Namazu and Dowlatabadi, 2015). On the other hand, despite the positive aspects, carsharing can intensify some urban mobility challenges, such as increased road congestion in terms of both intensity and duration (Diao et al., 2021), and car dependency (Boons and Bocken, 2018). This dilemma, which is also addressed by Shams Esfandabadi et al. (2020), requires to be analyzed through a framework based on a systems thinking approach, as a proper lens to look at the long-term effects of these services from the sustainability assessment point of view. To the best of the authors' knowledge, a systems thinking approach to monitor and capture the sustainability implications of carsharing services as a whole for urban transport in long term is lacking in the literature. In this regard, developing assessment frameworks and applying simulation models with a macro level of analysis, such as System Dynamics, is highly recommended for future studies to better asses and analyze the implications of carsharing and plan to incorporate carsharing services into the urban transport system to move towards sustainability.

4.2. Drafting inclusive marketing and training plans, and designing effective incentives

For a successful and sustainable diffusion of alternative technologies in transportation systems, keeping marketing programs and subsidies in place for long periods is essential (Keith et al., 2020; Struben and Sterman, 2008). This is while unawareness of people about carsharing has been mentioned as the main reason for a low diffusion of carsharing in some areas, such as in Italy (Rotaris, 2021). In this regard, a holistic plan to sufficiently encourage the public to use carsharing services seems to be required in many parts of the world, as the deployment of carsharing can accelerate the transition to sustainable urban mobility if accompanied by proper policies. Therefore, more research and investigative explorations are needed to fill this research gap, in particular in the following research directions: (i) formulating effective marketing strategies to increase the familiarity of people with carsharing and subsequently, increase the share of carsharing services from the whole urban transport; (ii) proposing innovative incentives for citizens as potential users, intermediary companies as service providers, and local government and relevant authorities as supporting stakeholders; (iii) conducting more context-sensitive research to customize the evaluation frameworks of different potential carsharing users characteristics in various geographical regions; (iv) designing effective plans to prevent switches from public transport to carsharing, and at the same time, increase switches from private cars to carsharing; and (v) formulating training programs for different segments of the population to increase knowledge about the potential role of carsharing in developing a sustainable society.

4.3. Analyzing the role of carsharing in achieving Sustainable Development Goals

When it comes to sustainability analysis, shared mobility and more specifically, carsharing is mainly analyzed from the environmental point of view. This is while the two other pillars of sustainability can also be affected by the development of these services. The three pillars of sustainability reflected in the United Nation's 2030 Agenda for Sustainable Development, containing 17 Sustainable Development Goals (SDGs) and 169 targets on a variety of perspectives, can serve as a guideline to analyze the diffusion of carsharing contribution to the progress towards achieving SDGs.

The emergence and development of carsharing platforms within the mobility system is notably in line with SDG 12, referring to ensuring sustainable consumption and production patterns. However, the expansion of carsharing services can potentially affect other SDGs and their associated targets. Carsharing literature contains a vast amount of research on the energy consumption and environmental effects of these services that are mostly linked with SDG 7 (affordable and clean energy) and SDG 13 (climate action), while carsharing research taking other SDGs into account is still in its infancy stage. For instance, social exclusion issues such as gender inequality in carsharing have been addressed in the research conducted by Alonso-Almeida (2019) and Singh (2020), although no direct implications have been elaborated for any specific SDG in their research. In other words, the explicit and implicit effects of carsharing services on the achievement of SDGs are still blurred, calling for more comprehensive research and developments to foster the progress towards sustainable development. In this regard, some potential avenues for future carsharing research towards achieving SDGs could be based on (i) developing initiatives to reduce inequalities and avoid social exclusion in using carsharing services, corresponding to SDG 5 and SDG 10, (ii) promoting sustainable consumption patterns and plans to increase economic growth, corresponding to SDG 8 and SDG 12, and (iii) contributing to building sustainable cities and communities, corresponding to SDG 11. Moreover, since the achievement of the SDGs has been affected by the COVID-19 pandemic (Ameli et al., 2022; Ranjbari et al., 2021b), a potential avenue for future carsharing research could be evaluating the long-term and short-term effects of the pandemic on the achievement of SDGs related to the urban mobility.

4.4. Developing circular economy indicators and circularity measurement system within the shared mobility domain

Transitioning from a linear economy to a circular economy, as a tool to promote sustainable development has brought economic, environmental, and social benefits to societies at the local and global scales (Shevchenko et al., 2021). Carsharing services through providing more utilization of shared vehicles instead of privately-owned vehicles can potentially support the transition towards a circular economy in the transportation system. In this regard, carsharing services, as a potential alternative for personal cars, can decrease the demand for car ownership and car manufacturing, resulting in less consumption of materials and resources as well as less pollution and waste generated by car manufacturers (Shams Esfandabadi et al., 2020). As a result, shared mobility services, in particular carsharing deserve to be put forward as a potential solution to implement the circular economy strategies in urban mobility systems.

Nevertheless, although the potential of shared mobility services vs. privately-owned vehicles to more effectively keep the current vehicles in use and at value seems to be in line with the circular economy principles, the research in this area is very limited. In the same vein, the literature on shared mobility services notably lacks (i) a clear circular economy conceptual framework and policy toolkit to manage how carsharing platforms can engage with the urban transport systems, (ii) an inclusive set of circular economy indicators and accordingly, a reliable circularity measurement system to monitor, measure and improve carsharing performance, and (iii) sufficient clarifications on how shared mobility services affect the circularity of urban mobility business models over time in terms of various factors, such as reduction of raw materials for manufacturing the vehicles, reduction of fossil fuels consumption, and stakeholders structure in the whole transport supply chain. The identified gaps in this arena provide potential lines of research in the future of carsharing services towards creating circular and sustainable mobility systems.

4.5. Assessing the implications of the COVID-19 pandemic for carsharing

The impacts of the COVID-19 pandemic on different aspects of human lives are undeniable (Ranjbari et al., 2021c). Restrictions on the mobility of people during the pandemic and the requirement of keeping a safe distance from others changed the behavior of people in using various modes of transportation during this period. Therefore, long-term impacts on the transport sector in the post-pandemic era seemed likely, and it was projected that the new normal situation after the pandemic could provide an opportunity to move towards a more sustainable transport sector (Zhang and Zhang, 2021). Nevertheless, carsharing was identified as a sector seriously suffering from the outbreak of the COVID-19 pandemic (Garaus and Garaus, 2021).

Despite a significant amount of research on the changes caused by the lockdowns and mobility restrictions on the overall urban transportation (Andara et al., 2021; Ravina et al., 2021; Zhou et al., 2021), limited research in the carsharing domain has pointed to changes borne by these services during the pandemic, and opportunities and threats in the normal future after that. For instance, concerning the pandemic period, Garaus and Garaus (2021) analyzed the consumers' intention to use carsharing during the pandemic in Germany; Alonso-Almeida (2022) studied the drivers and barriers, as well as the usage and advantages of carsharing during the pandemic; and Turoń et al. (2021) studied the required aspects to be considered in the context of a pandemic when modeling and optimizing energy services for electric carsharing, as a part of electric shared mobility services. Also with regard to the movement towards decarbonization of the transport sector in the new normal after COVID-19, Zhang and Zhang (2021) analyzed the reduction potential od CO_2 emissions by 2060 as a result of change in the lifestyle of the people and the usage of transport modes including carsharing. Therefore, a comprehensive overview of the short-term and long-term implications of the pandemic for the usage of carsharing is still lacking. As a result, decision-makers need to take potential scenarios and policies related to the COVID-19 outbreak into account to better manage the diffusion of carsharing towards a sustainable transport system.

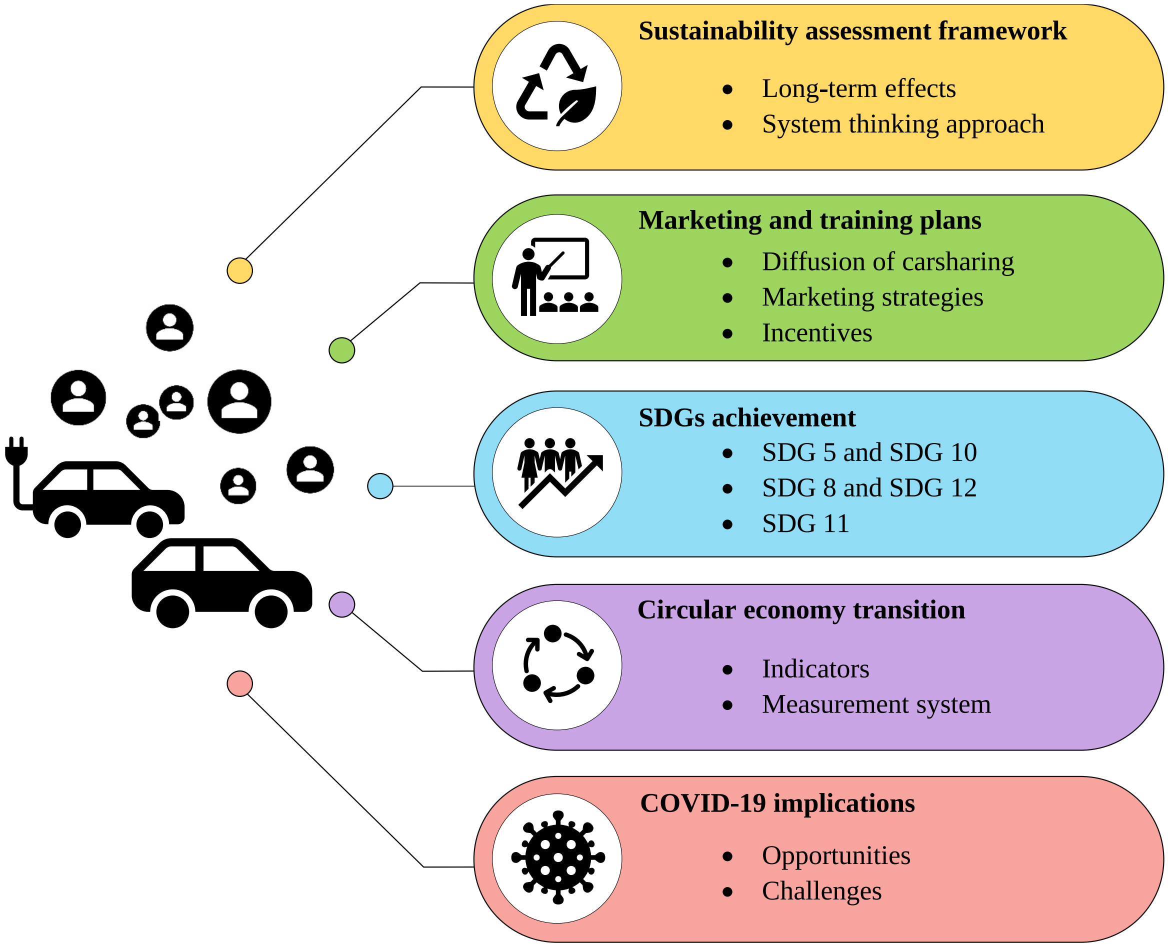


Figure 9. The research agenda for future research in the field of carsharing.

5. Concluding remarks

Carsharing services with the aim of reducing private car ownership have been increasing in recent years. A huge amount of research has been carried out on carsharing considering different aspects from business models and operational challenges to sustainability aspects and travel behavior, leading to fragmented literature. As the first attempt in the literature, our research provided a systematic bibliometric analysis on carsharing research, covering a total of 729 peer-reviewed journal articles in WoS that were published by the end of June 2021.

The research contributes to the existing studies research through (i) analyzing hotspots and research tendencies in the carsharing literature by employing keywords and text mining analyses, (ii) discovering the main research themes building carsharing research background by applying a bibliographic coupling analysis, and (iii) identifying potential directions for future carsharing research. The results uncovered four main research themes of carsharing literature, including (1) collaborative consumption and carsharing business models development in the context of sustainable urban transport, (2) carsharing adoption: user behavior, intention, and preferences, (3) carsharing operational challenges: infrastructure and fleet management, and (4) technological advancement towards deployment of shared autonomous vehicles and MaaS.

Based on the provided inclusive map of the carsharing research background to date, five main research gaps were identified and proposed for future studies. First, since the actual impact of carsharing services on transitioning towards building sustainable cities is still unclear, developing a long-term sustainability assessment framework for carsharing activities could be a promising direction for further studies. Second, in order to increase the awareness and familiarity of people with carsharing services, developing inclusive marketing and social exposure plans to encourage all actors could help better promote carsharing usage more sustainably. Third, carsharing is basically developed in line with SDG 12 and can affect other SDGs of the UN's 2030 Agenda for Sustainable Development. Analyzing the role of carsharing in the achievement of different SDGs and their targets could support more effective planning to step towards sustainable cities and communities. Fourth, literature on carsharing lacks circular economy indicators and circularity measurement systems to assess the circularity of the activities taking place in relation with carsharing, which deserves to be considered in future research. And finally, despite the significant implications of the COVID-19 pandemic for urban transportation systems, studies on the effects of pandemic on the future of carsharing is scare, which can be further supported by researchers in future studies.

The present research had two limitations. Firstly, we used bibliographic coupling analysis as a base for article clustering in our analysis. Employing other article clustering methods such as co-citation analysis is recommended to compare the results and highlight the amendments. Secondly, this research was conducted based on data collected from the WoS database. Incorporating other well-known databases such as Scopus may help improve the results due to potential differences in the coverage of scientific literature on various domains and disciplines.

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