

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

Original

Carsharing services in sustainable urban transport: An inclusive science map of the field / SHAMS ESFANDABADI, Z., Diana, M., Zanetti, M.. - In: JOURNAL OF CLEANER PRODUCTION. - ISSN 0959-6526. - ELETTRONICO. - 357:(2022), p. 131981. [10.1016/j.jclepro.2022.131981]

Availability:

This version is available at: 11583/2972340 since: 2022-10-15T12:23:10Z

Publisher:

ELSEVIER SCI LTD

Published

DOI:10.1016/j.jclepro.2022.131981

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22 advancement towards deployment of shared autonomous vehicles and mobility as a service. The
23 results showed that the carsharing literature lacks (i) a well-established and comprehensive long-
24 term sustainability assessment framework, (ii) inclusive and integrative marketing and training
25 plans, as well as effective incentives, (iii) a holistic analysis of the role of carsharing in the
26 achievement of Sustainable Development Goals, (iv) reliable circular economy indicators
27 designed to measure the circularity of carsharing to help transitioning towards a circular
28 economy, and (v) a timely broad analysis on the implications of the COVID-19 pandemic and
29 the future of carsharing post pandemic era, which call for more investigations in the future. The
30 provided insights support both researchers and policy-makers by shedding light on carsharing
31 services research by providing a state-of-the-art of carsharing studies and developments up to
32 date, uncovering the emergent research themes and trends, and identifying research gaps for
33 future studies towards better positioning carsharing services in sustainable cities developments.

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

35

36 **1. Introduction**

37 In recent years, the concept of sharing economy has emerged as a new consumption style with
38 the potential to support new production and effective use of products (Kurusu et al., 2021)
39 through giving temporary access (i.e., without ownership transferring) enabled by using online
40 platforms (Ranjbari et al., 2018). Due to the increasing population of urban areas, transport
41 activities have become more critical than ever in developing sustainable cities action plans for
42 local and regional governments and authorities (Martins et al., 2021). In this regard, carsharing
43 services have gained momentum as a tool for transport policy-makers, since their improvements

44 in the urban transport system can reduce the number of cars, leading to more sustainable cities
45 (Ampudia-Renuncio et al., 2018). Carsharing, by providing the benefits of a private vehicle
46 without owning it through sharing the vehicles by different drivers at different times, supports
47 the transition of private mobility from ownership to service use (Shams Esfandabadi et al.,
48 2020). Whether these services are provided through peer-to-peer (P2P) or business-to-consumer
49 (B2C) platforms, carsharing consists of round-trip or one-way services in which vehicles are
50 available for use without drivers. Therefore, carsharing differs from ride-hailing in that there is
51 no driver to make a suitable trip for the service user, and differs from ride-sharing in that only
52 the use of a vehicle is shared not a trip.

53 A substantial amount of scientific research on different aspects of carsharing has been conducted
54 in the last decade. The major subject areas include but are not limited to business models
55 (Münzel et al., 2019; Yun et al., 2020), sustainability aspects (Bocken et al., 2020; Hartl et al.,
56 2018), operational challenges (Balac et al., 2019; Huang et al., 2018; Jian et al., 2016), adoption
57 (Burghard and Dütschke, 2019; Chun et al., 2019; Ullah et al., 2019), demand (Li and
58 Kamargianni, 2020; Zhang et al., 2019), technological advancements (Iacobucci et al., 2018;
59 Vosoghi et al., 2020), and travel behavior (de Luca and Di Pace, 2015; Jain et al., 2020;
60 Matowicki et al., 2021). Besides, few review articles have been published addressing different
61 aspects of carsharing services, such as price and taxation levels (Schwieterman and Bieszczat,
62 2017), free-floating carsharing (Mattia et al., 2019), business models (Lagadic et al., 2019),
63 vehicle relocation problem in one-way carsharing networks (Illgen and Höck, 2019), urban
64 sustainability impacts (Roblek et al., 2021), and electric carsharing (Liao and Correia, 2020).
65 Nevertheless, although shared mobility strategies such as carsharing have gained significant
66 attention in research communities, even media, and public debate during recent years, the overall

67 impact of the sharing economy model on transport is still blurred (Standing et al., 2018).
68 Moreover, a holistic image of the carsharing research themes, hotspots, and tendencies is lacking
69 within the fragmented literature of carsharing services. Therefore, to fill the identified gap, this
70 systematic bibliometric review aims to provide a comprehensive map of the body of knowledge
71 on carsharing services.

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

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

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

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

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

83 The structure of the paper is as follows. Materials, methods, and the overall research framework
84 are explained in Section 2. The main findings of the research are presented and discussed in three
85 sub-sections, representing descriptive analysis: Publication developments (Section 3.1),
86 carsharing research hotspots, tendencies, and orientations (Section 3.2), and major emergent

87 carsharing research themes (Section 3.3). Section 4 provides the identified potential research
88 direction for future studies on carsharing. Finally, Section 5 delivers the conclusions and
89 limitations of the research.

90 **2. Materials, methods, and research framework**

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

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

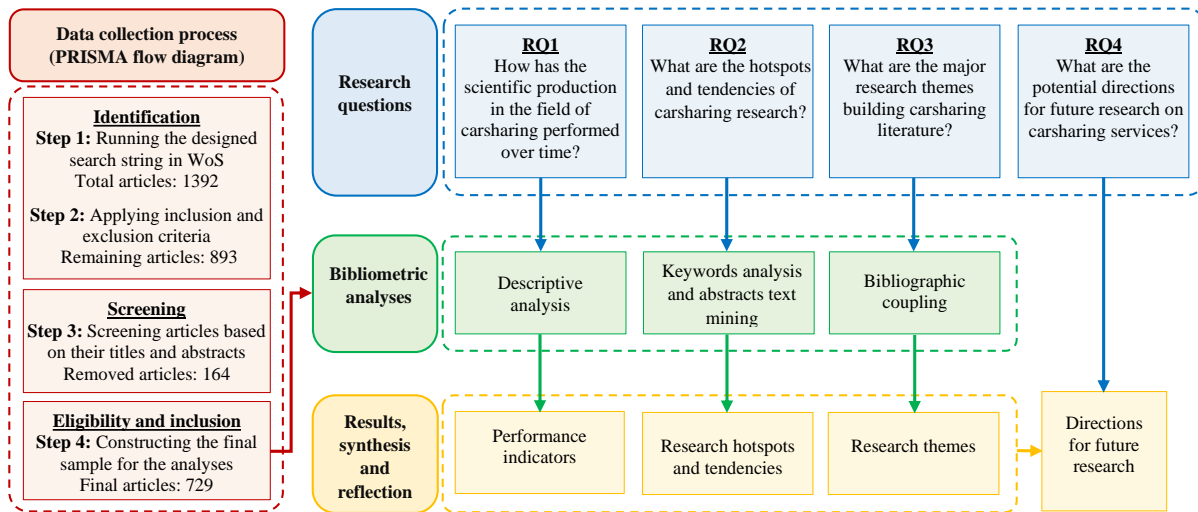


Figure 1. Research framework design.

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

121 part of the search string, which is in parenthesis, was limited with "passenger*" AND
 122 "transport*" to avoid capturing papers from clinical research studies referring to shared care or
 123 caring of patients in healthcare facilities. In the next step, the Web of Science (WoS) Core
 124 Collection citation database was considered as the main database for conducting this review.

125 The initial run of the search string in the topic of documents (i.e., title, abstract, author keywords,
 126 and keywords plus) returned 1,392 articles without any time limitation. No time limitation was
 127 considered to cover the whole scientific production up to date. Then, based on the defined
 128 inclusion criteria, only peer-reviewed journal articles in the English language were included in
 129 the sample. In this stage, other types of documents, such as conference proceedings, editorials,
 130 reports, book chapters, etc. were excluded from the data, leading to removing 499 documents.
 131 The titles and abstracts of the remaining 893 articles were manually checked to see whether they
 132 are relevant to the focus of this review. On this basis, 164 articles that mainly had focused on
 133 other types of shared mobility services, such as bike-sharing, scooter sharing, bus, and ride-
 134 hailing were excluded from the sample. As a result, a total of 729 articles published from 1980 to
 135 2021 were selected as the base for the present review. The details of the adopted search protocol
 136 to collect the final sample for analysis are tabulated in Table 1.

137 **Table 1**

138 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

139

140 **2.2. Analysis methods**

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

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

149 Second, keyword analysis of the author keywords of the articles (N= 1,674) was combined with
150 a text mining analysis on the concatenation of the titles and abstracts of the articles (N= 729), to
151 identify the hotspots, research tendencies, and theoretical orientations of carsharing research
152 which has been conducted so far, addressing RQ2. Keywords defined by the authors of an article
153 reflect the core concepts of the research (Chiang, 2020). In this phase, keywords were analyzed
154 based on their occurrence, co-occurrence (i.e. joint occurrence of different keywords in the same
155 paper), and time overlay to map the intensity of keywords and also mutual interconnections
156 between them (Mustak et al., 2021). As a crucial step before conducting keyword-based
157 analyses, a data cleaning on the author keywords was done to increase the reliability of the

158 analysis (Ranjbari et al., 2020). In this vein, the following settings were performed: (i) keyword
159 abbreviations and their full forms were merged, (ii) singular and plural forms of the keywords
160 were considered the same to avoid duplicating, (iii) the American and British writing styles were
161 unified based on the American style, and (iv) parentheses within the keywords were removed.

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

179 Third, due to the large number of articles (N=729), a data clustering technique using
180 bibliographic coupling networks was carried out to group the articles based on the bibliographic
181 coupling links (i.e., the number of times that every two articles have simultaneously cited
182 another article). Hence, a bibliographic coupling analysis using VOSviewer was performed to
183 uncover the main research themes building carsharing literature, addressing RQ3. The
184 bibliographic coupling clustering of articles, as one of the more accurate bibliographic
185 techniques to quantitatively assess the relatedness between two scientific documents, with a
186 forward-looking perspective leads to unfolding the more recent research themes (Belussi et al.,
187 2019) within the carsharing research domain up to date. The bibliographic coupling module of
188 VOSviewer provides a map of clusters automatically based on the data presented to the software.
189 However, since the process is conducted through a machine-driven algorithm, as proposed by
190 van Eck and Waltman (2017), different values for the resolution parameter (Waltman et al.,
191 2010) were tested to achieve a satisfactory level of detail in clustering. As a result, the number of
192 clusters was decided to be four as a further breakdown of the network did not add any further
193 homogeneous topics.

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

196 **3. Results and discussion**

197 To clearly address the RQs of the present review, the results are presented in the following three
198 subsections. On this basis, Section 3.1 presents the descriptive analysis to answer the RQ1,
199 including publication evolution over time, main contributing journals to the carsharing research
200 area, and geographical distribution of publications. RQ2 is answered in Section 3.2, which

201 delivers the discovered research hotspots, tendencies, and orientations within the carsharing
202 literature. Finally, the results of the bibliographic coupling analysis are provided in Section 3.3 to
203 address the RQ3.

204 **3.1. Descriptive analysis: Publication developments**

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

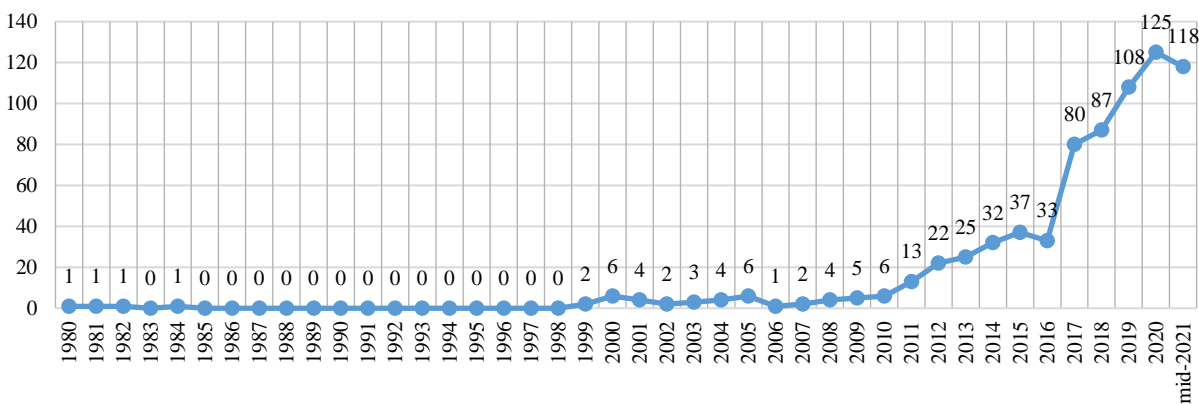
207 **RQ1.** How has the scientific production in the field of carsharing performed over time?

208 **3.1.1. Publications trend over time**

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

215 As can be seen in Figure 2, the first article published in WoS in the field of carsharing services
216 dates back to 1980. The number of published articles from 1980 to 2010 remain between 0 and 6
217 per year but in 2011 this number exceeds double. A continuous growth starts from 2011 (except
218 for 2016) and through an exponential increase, the number of published articles in the year 2020
219 reached 125. The leap between 2016 and 2017 is also noticeable, which might be due to the
220 massive entry into the market of free-floating services in those years that boosted the number of

221 carsharing subscribers around the world. The number of published articles only in the first half of
 222 2021 (from January 1st to July 1st) was 118, which is expected to lead to a higher record than
 223 2020 by the end of the year. Therefore, this field seems to be still in its expansion period that will
 224 probably continue as long as the carsharing services continue their diffusion in different
 225 geographical regions beyond the western hemisphere.



226

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

227

228 **3.1.2. Leading journals**

229 A total of 255 journals contributed to the publication of the 729 articles in the studied field. It
 230 was found that 12 journals, as listed in Table 2, have published at least 10 articles. These journals
 231 cooperatively contain 335 papers, representing approximately 45.95% of our sample articles. In
 232 addition to the number of carsharing-related articles and their citations in these journals, the
 233 share of carsharing articles from the total number of articles published by these journals are
 234 reported in Table 2. Since our search was limited to peer-reviewed articles and review papers,
 235 this limitation was also considered to extract the total number of articles from WoS for each
 236 journal. Furthermore, regardless of the publication year of the first article published by the
 237 journals and indexed in WoS, the time horizon for computing the total number of articles was

238 considered to be 1999 (consistent with the main growth of publications in the carsharing field of
239 study as shown in Figure 2) to the end of June, 2021, when the main data for the analyses were
240 taken from WoS. Table 2 also reports the average publication year (APY) of the carsharing-
241 related papers, which indicates a mean of the publication year of the carsharing articles published
242 in the listed journals.

243 As can be seen in Table 2, out of the presented 12 journals, 10 journals directly focus on the
244 transportation field of study. The other two journals, *Sustainability* and *Journal of Cleaner*
245 *Production*, focus on environmental studies and green and sustainable science and technology.
246 Also, the share of carsharing-related research from the total number of articles shows that the
247 highest ratio (3.72%) refers to *International Journal of Sustainable Transportation*, whose
248 category (in addition to transportation) is similar to the abovementioned journals. Therefore, this
249 may indicate that a part of attention towards carsharing is highly linked with its sustainability
250 and environmental aspects. Nevertheless, *Journal of Cleaner Production* and *Sustainability* have
251 the lowest share of carsharing-related research from their overall articles published (0.06% and
252 0.13%, respectively), which highlights the difference between the main focus in these journals
253 and the transport-related ones.

254 Furthermore, the APY of the articles published by the journals shows that *Transportation*
255 *Research Record* is older than other journals in terms of the active publication of articles in the
256 field of carsharing (APY of 2013.8 for 45 articles). On the other side of the spectrum, *Journal of*
257 *Advanced Transportation* (APY of 2019.4 for 15 articles) and *Sustainability* (APY of 2019.3 for
258 46 articles) are the most recently active journals contributing to the literature on carsharing.
259 Referring to Figure 3, which shows the publication of carsharing research in the considered 12

260 journals over time, it can be inferred that *Transportation Research Record* has been almost
 261 continuously active in the publication of carsharing research since 2007 (except in 2021 that no
 262 article in the carsharing field was published in this journal by the end of June). Although the
 263 share of carsharing research from the total articles published in this journal is 0.36%, the
 264 continuous contribution of this journal in the publication of carsharing research has resulted in
 265 the lowest APY (as reported in Table 2) that highlights the role of this journal in research in this
 266 field.

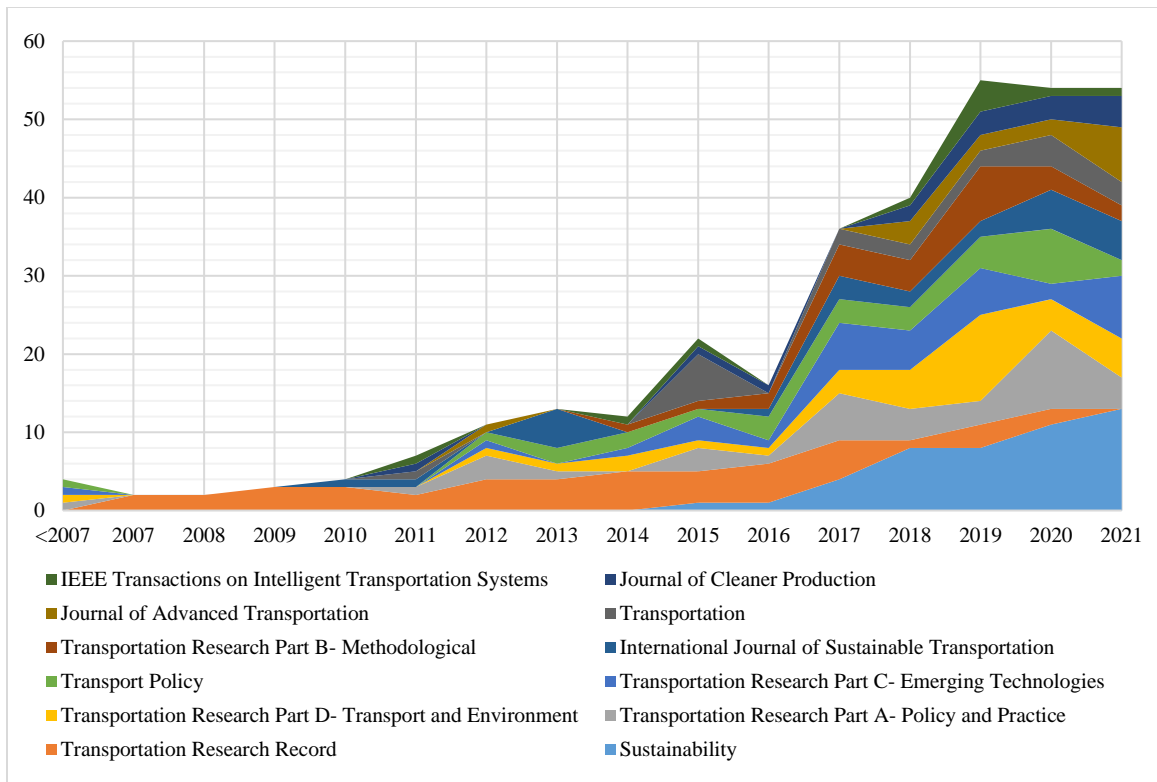
267 **Table 2**

268 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

269 * Carsharing

270



271

272

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

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3.1.3. Contribution and collaboration of countries

274

A total of 57 countries contributed to the formation of carsharing literature within the WoS

275

database. Figure 4 illustrated the collaboration network among these countries. The size and

276

color of the frames used for the countries correspond to their number of articles and their APY,

277

respectively. Besides, the availability of a link between two countries indicates their co-

278

authorship and the thickness of the links shows the occurrence of such co-authorship. In order to

279

clarify authorship and co-authorship of the countries, Table 3 provides the list of the top 10

280

contributing countries in terms of their articles, international collaborators, and collaborations,

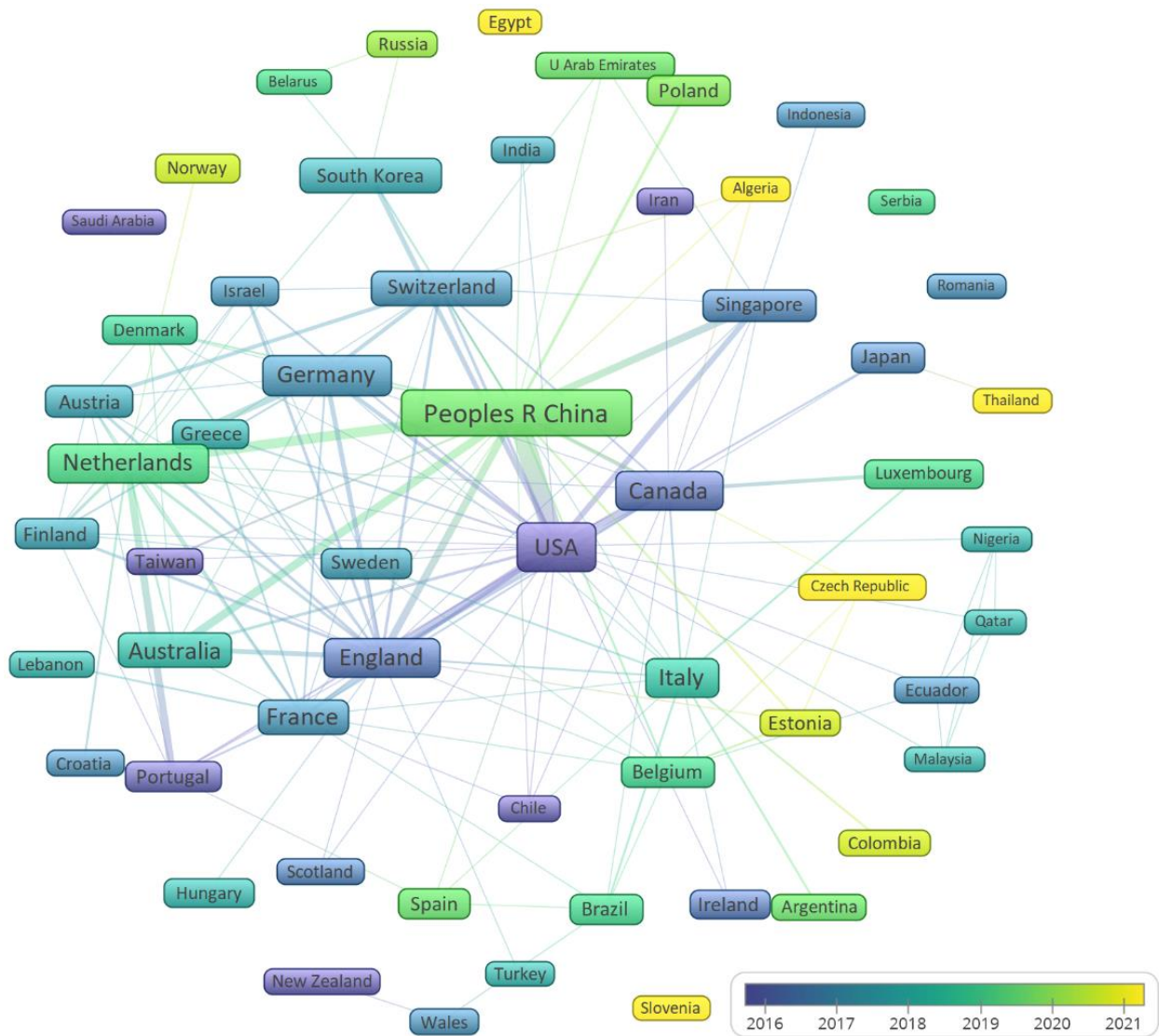
281

and Table 4 gives an overview of the most frequent international collaborations among countries.

282

As can be seen in Table 3, the USA is ranked first with regard to all the mentioned 3 rankings,

283 and based on Table 4, its most frequent collaborators are China (23 collaborations), England (9
284 collaborations), Canada (7 collaborations), and Singapore (6 collaborations). Moreover, Table 5
285 introduces the most recent and also the oldest contributing countries based on their APY. Based
286 on this table, the Czech Republic, Algeria, Thailand, Egypt, and Slovenia with an APY of 2021
287 have started their investigations on carsharing very recently. On the other side of the spectrum,
288 Taiwan and the USA have the lowest APY indicating that they have considered this research
289 topic much earlier than the other countries. Since the USA has the highest number of articles and
290 at the same time, is very old in terms of the APY, we can consider this country as a pioneer in
291 terms of research production in the field of carsharing.



292

293

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

294

Table 3

295 List of the top 10 countries contributing to the carsharing research in terms of (a) the number of articles, (b) the
 296 number of collaborating partners, and (c) the number of collaborations.
 297

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			

298

299 **Table 4**

300 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

301

302 **Table 5**

303 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

304

305 **3.2. Carsharing research hotspots, tendencies, and orientations**

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

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

309 **3.2.1. Keyword-based analysis**

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

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

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

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

343 Table 6 provides more details on the occurrences and APY for some selected keywords from
 344 Figure 5. A comparison of the APYs of various forms of carsharing in Table 7 shows that on
 345 average, P2P carsharing (2018.8) is more recently focused on by the researchers, followed by
 346 free-floating carsharing (2018.1), one-way carsharing (2017.4), and round-trip carsharing
 347 (2016.7), respectively.

348 **Table 6**

349 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

350

351 3.2.2. Text mining analysis

352 Through using the text mining function of VOSviewer for our corpus of documents, a list of
353 14,725 noun phrases was identified as the potential terms describing the research topics and
354 themes of the carsharing field. To capture the terms that are sufficiently frequent to be potential
355 descriptors of our considered subject area, the terms with a minimum of 3 occurrences based on
356 a binary counting method (in which counting is based on the presence or absence of a term, not
357 all the occurrences of a term within a single article) were considered for further analysis, leading
358 to a list of 1,598 terms. Furthermore, according to Van Eck and Waltman (2011), to remove
359 general terms such as paper, approach, and article, which fail to describe a specific topic, only
360 the 60% most relevant terms based on the statistical method applied in the software were
361 considered, resulting in a list of 959 terms. We additionally checked the obtained list thoroughly
362 and removed the remaining irrelevant terms such as the name of the cities and countries. Finally,
363 754 terms remained for further analysis.

364 Figure 6 illustrates the time overlay of the terms extracted from titles and abstracts of our corpus
365 of articles. The range of colors in this figure refers to the recentness of the APY of the identified
366 terms. Besides, similar to Figure 5, the fonts and size of the circles in Figure 6 reflect the
367 occurrence of the terms. As it can be seen, the nouns ‘algorithm’, ‘relocation’, and ‘one-way’

368 with 54, 51, and 44 occurrences are the identified most frequent terms in this figure, showing the
369 research tendency towards optimization problems and algorithms in the field of carsharing.

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

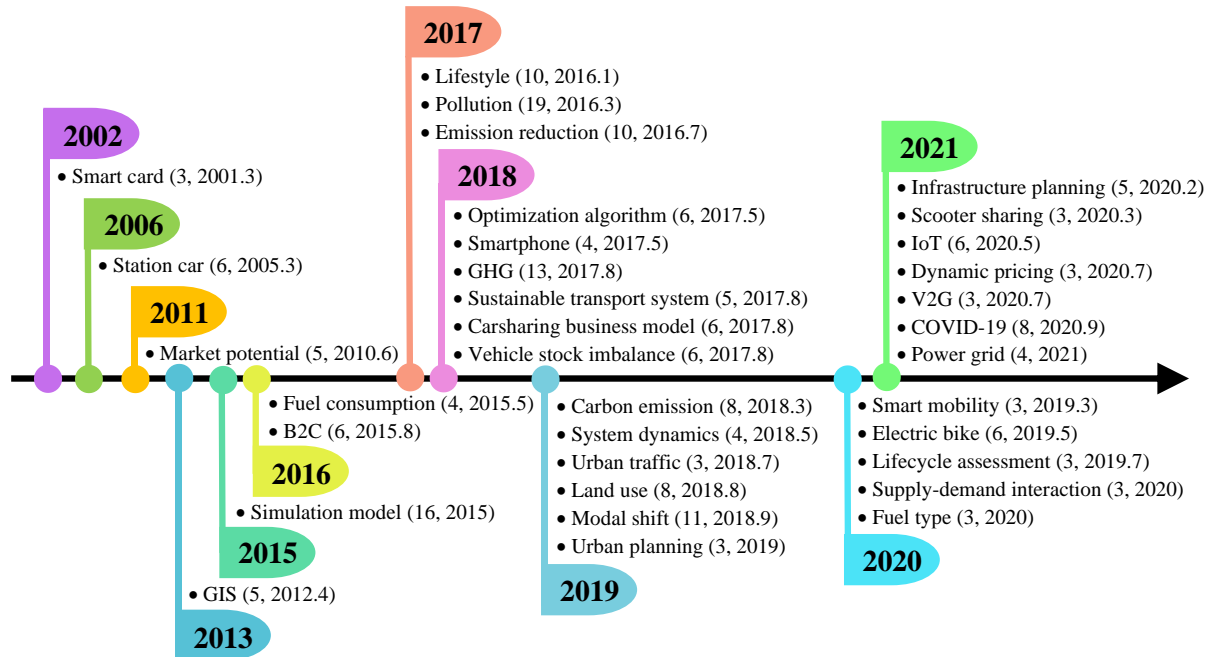
381 **Legend:** **IoT:** Internet of things; **ICT:** Information and communications technology; **P2P:** Peer-to-peer; **B2C:** Business-to-
382 consumer; **EV:** Electric vehicle; **SEV:** shared electric vehicle; **MaaS:** Mobility as a Service; **SAV:** Shared autonomous vehicle;
383 **SAEV:** Shared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

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

386

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

404 stronger tendency towards more technological advancements and building more sustainable and
 405 smart cities.



406
 407 **Figure 7.** Timeline of the hotspots and research tendencies within carsharing study area extracted from title and
 408 abstract of the articles (occurrences and average publication year in parentheses)

409
 410 **3.3. Bibliographic coupling analysis: Discovering major emergent carsharing research**
 411 **themes**

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

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

414 The article clustering technique based on bibliographic coupling links among the articles was
 415 used. Table 8 provides the details of the carsharing research clusters in terms of the number of
 416 articles and APY. In this regard, two points were considered in constructing the bibliometric

417 network. Firstly, review papers (N=24) were excluded from the articles (N= 729) in this stage
 418 due to their high link strength, which may make the clustering results biased. In bibliographic
 419 coupling networks, the link strength between two documents refers to the number of references
 420 they have in common. The more references they have in common, the higher the link strength is.
 421 Secondly, among the remained 705 articles, 19 articles that did not have a common reference
 422 with others were also excluded from the data. Consequently, the bibliographic coupling network
 423 was constructed including a total of 686 articles in the carsharing literature.

424 **Table 8**

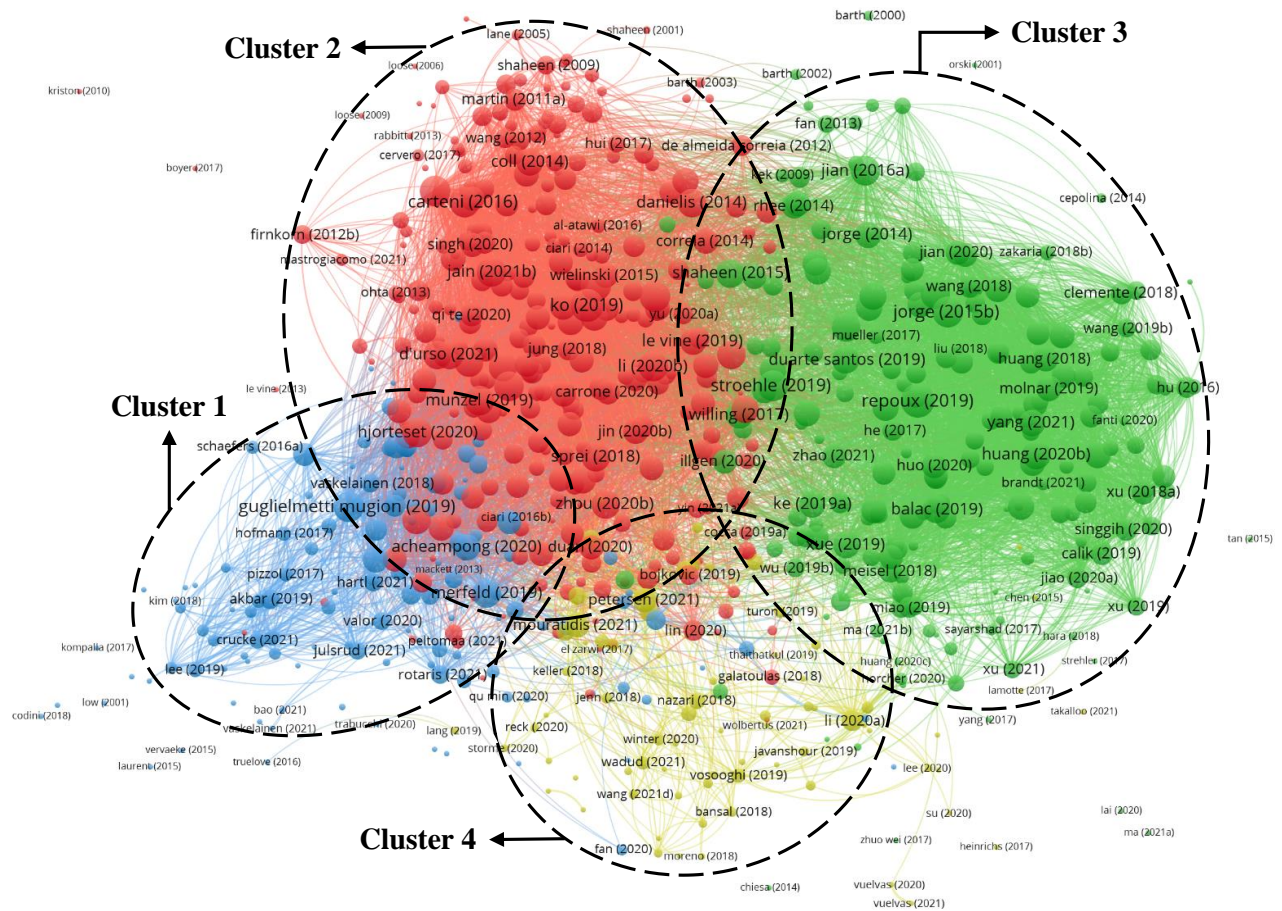
425 Bibliographic coupling clusters details.

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)
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426

427 As a result, the analysis revealed four main emergent research themes of the carsharing literature
428 as follows: (i) collaborative consumption and carsharing business models development in the
429 context of sustainable urban transport, (ii) carsharing adoption: user behavior, intention, and
430 preferences, (iii) carsharing operational challenges: infrastructure and fleet management, and (iv)
431 technological advancement towards deployment of shared autonomous vehicles and MaaS. The
432 bibliographic network of the clustered articles is visualized in Figure 8. In this Figure, nodes
433 represent the articles, and their size and font show their total link strength. Therefore, larger
434 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.

435

436

437

438 **3.3.1. Cluster 1: Collaborative consumption and carsharing business models**

439 **development in the context of sustainable urban transport**

440 Collaborative consumption refers to the P2P-based activities of obtaining, giving, or sharing the
 441 access to goods and services enabled by information and communication technologies (Hamari et
 442 al., 2016). One of the most widespread applications of the concept of collaborative consumption,

443 as a core of the sharing economy, has emerged in the mobility sector through providing
444 carsharing services (Novikova, 2017). Carsharing services based on collaborative consumption
445 have been increasingly developed as a promising solution for sustainable transportation (Hartl
446 and Hofmann, 2021) to enhance accessibility and reduce the negative externalities produced by
447 the transport sector (Rotaris, 2021).

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

457 In this regard, various business model types have been characterized by scholars within the
458 literature. For instance, Münzel et al. (2018) highlighted four different business models for
459 carsharing services, including (i) cooperative with a not-for-profit orientation and interest for
460 sharing vehicles, (ii and iii) B2C divided into roundtrip and one-way models, which refers to a
461 company owning a fleet of cars to rent them on-demand for a temporarily use, and (iv) P2P
462 carsharing that addresses sharing cars between individuals with the help of a company as a
463 mediating platform, mainly enabled by using online platforms. Most notably, P2P carsharing, as

464 a socio-technical innovation, has gained momentum intending to support a transition from the
465 traditional to a more sustainable urban mobility system (Valor, 2020).

466 According to Yun et al. (2020), the idea of promoting carsharing services until 2000 was mainly
467 focused on addressing environmental concerns, such as emission reduction through decreasing
468 car ownership and providing eco-efficient services. However, professional carsharing
469 development by environmentally concerned citizens shifted to market expansion through user-
470 led innovation processes (Truffer, 2003) and technologies, such as relocation algorithms for free-
471 floating car-sharing systems (Weikl and Bogenberger, 2013; Yun et al., 2020). Research has
472 shown that personal car-based mobility in cities is losing its share of urban travels by entering
473 new mobility business models such as carsharing, which delivers functionality rather than
474 ownership (Bocken et al., 2020, 2014; Kent and Dowling, 2013). In their research on the
475 implications of the sharing economy for transport, Standing et al. (2018) highlighted the trend to
476 avoid assets ownership, trust, and using online platforms as facilitating factors of the growth of
477 sharing economy and collaborative consumption in transport. In this regard, member-to-vehicle
478 ratios, market segments, parking approaches, technology, insurance, and vehicle and fuel variety
479 have been highlighted in the literature as the key factors characterizing carsharing operations
480 growth in the carsharing market (Perboli et al., 2018; Ranjbari et al., 2019; Shaheen and Cohen,
481 2007).

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

486 (Münzel et al., 2018), the effects of institutional logics on the carsharing business model
487 development (Vaskelainen and Münzel, 2018), carsharing business models and tariff simulation
488 (Perboli et al., 2018), and upscaling strategies for carsharing business models (Meijer et al.,
489 2019). Besides, some articles in this cluster address the environmental impacts of carsharing
490 (Shams Esfandabadi et al., 2020) and its sustainability (Akyelken et al., 2018; Bocken et al.,
491 2020; Hartl et al., 2018), since carsharing is a promising idea towards transportation
492 sustainability especially when electric vehicles (EVs) are utilized to provide carsharing services
493 (Kot, 2020). Shams Esfandabadi et al. (2020) pointed to the circular economy approach in the
494 development of carsharing services and highlighted the role of car manufacturers, regulators, and
495 service providers in the organization of carsharing platforms and services. In this vein, they
496 highlighted the effect of positive and negative effects of carsharing on the pollution of air, water,
497 and soil. Nevertheless, Hartl et al. (2018) showed that the sustainable impact of carsharing is
498 perceived by the users as a positive side effect rather than a main argument; and environmental
499 concerns become important for carsharing users when they decide to use P2P over B2C services.

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

509 explorations. It is likely that the above-mentioned different carsharing schemes have a
510 diversified impact in terms of environmental sustainability.

511 **3.3.2. Cluster 2: Carsharing adoption: User behavior, intention, and preferences**

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

520 Studies have pointed to different socio-demographic, socio-economic, and attitudinal variables
521 affecting the utilization of carsharing by commuters in different regions and cities. Research
522 conducted by Burghard and Dütschke (2019) in Germany, Matowicki et al. (2021) in the Czech
523 Republic, Hjortset and Böcker (2020) in Norway, Ramos et al. (2020) in Italian and Swedish
524 cities, Kim et al. (2017) in the Netherlands, and Li and Kamargianni (2019) in China are a few
525 examples in this regard. Furthermore, Bulteau et al. (2019) explored a comprehensive set of
526 socio-demographic and socio-economic, interpersonal, and contextual variables in Paris to
527 analyze the possibility of the carpooling and carsharing implementation in this region. Prieto et
528 al. (Prieto et al., 2017) studied the socio-demographic drivers of the intention to adopt carsharing
529 in London, Madrid, Paris, and Tokyo, and concluded that the probability of carsharing adoption
530 is significantly higher among those who live in the city center, who are male, and who are highly

531 educated. Similarly, Ceccato and Diana (2018) found that young males living in low-size and
532 high-income households with many workers and few cars constitute the main share of carsharing
533 members in Turin, Italy. The majority of studies concerning the switching intention among
534 various transport modes, and more specifically switching towards and from carsharing, have
535 implications both for service providers and the authorities, the latter with a more emphasis.
536 Based on the obtained data from two surveys in Turin, Ceccato et al. (2021) highlighted that the
537 willingness to switch towards new transport modes is stronger for people with multimodal travel
538 habits. Also, Diana and Ceccato (2019) found that both personal car drivers and public transport
539 users are willing to walk up to five minutes to reach a shared car; and in contrast with a majority
540 of the personal car drivers, public transport users are more likely to switch to carsharing if the
541 cost of these services is lower. Therefore, they called for more attention by the decision-makers
542 and authorities to increase the attractiveness of public transport with respect to carsharing to
543 avoid switches from public transport.

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

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

555 Moreover, the adoption of carsharing services has resulted in different environmental outcomes,
556 which should be carefully considered by the authorities and regulators. On the one hand, the
557 reduction of the number of the required passenger cars to satisfy the mobility demand and the
558 substitution of more fuel-efficient shared vehicles for private vehicles use result in the reduction
559 of GHG emissions; and on the other hand, attracting car-less commuters towards using
560 carsharing leads to increasing GHG emissions (Jung and Koo, 2018). For instance, a study
561 conducted by Namazu and Dowlatabadi (2015) showed that using a newer and optimized
562 carsharing fleet in a Canadian context can potentially reduce the GHG emission by more than
563 30% regardless of modal shifts. Furthermore, despite a large growth potential for carsharing
564 market share in Turin (Ceccato and Diana, 2018), Chicco and Diana (2021) found that the
565 carsharing modal share in this Italian city might grow up to a maximum of 10% out of all trips
566 made by any means, for all distances, by the city population aged 18 or more; nevertheless,
567 potential environmental benefits from this growth are partially offset due to the switches from
568 public transport and active modes to carsharing services. Chen and Kockelman (2016) analyzed
569 the lifecycle impacts of carsharing on energy consumption and GHG emissions in the USA and
570 concluded that net savings resulting from the adoption of carsharing are expected to be 5%
571 across all households. Based on their research, modal shift, avoided travel, fuel consumption, and
572 savings in parking infrastructure demands result in 5% savings in all household transport-related
573 energy use and GHG emissions; however, since a part of this saving is then spent on other goods
574 and services, the net savings across all households in the USA would be 3%. Therefore, more
575 comprehensive studies are encouraged to be conducted by researchers in this regard to better

576 help regulators and policy-makers in their decision-making processes regarding carsharing
577 development.

578 **3.3.3. Cluster 3: Carsharing operational challenges: Infrastructure and fleet** 579 **management**

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

585 Research shows that depot locations can affect the usage of carsharing services (Jian et al.,
586 2016). Therefore, deciding on the optimal location of the shared vehicle depots plays a key role
587 in the profitability of carsharing service providers (Correia and Antunes, 2012). Incorporating
588 EVs into carsharing programs adds to the importance of the optimal location of the depots and
589 charging stations because of the limited driving range and low charging speed of EVs, which are
590 considered as discouragements for their broad adoption (Hu et al., 2019). Moving towards the
591 decarbonization of transportation, as a leading contributor to the emission of GHGs, draws more
592 attention towards the diffusion of alternative-fuel vehicles, such as EVs (Keith et al., 2020); and
593 therefore, shared EVs have been the focus of many researchers in the field of carsharing. As a
594 result, in line with the timeline presented in Figure 7, the challenges with the state-of-charge
595 (SOC) of EVs and the possible opportunities regarding the vehicle-to-grid (V2G) electricity
596 selling in EV sharing have been the subject of recent studies in the field of carsharing research.
597 Kahlen et al. (2018) focused on the virtual power plants (VPPs) potentials in balancing the

598 electricity smart grids and analyzed the exchange of electricity between EVs and the grid,
599 addressing the demand patterns of electric carsharing vehicles. The simulation-based
600 optimization model developed by Zhao et al. (2021) to address a system infrastructure design
601 problem for an electric autonomous vehicle sharing, the optimization model proposed by Zhang
602 et al. (2020) to investigate the benefits of integrating V2G in electric carsharing, and the discrete
603 event simulation model presented by Illgen and Höck (2018) to examine the operation of EVs in
604 carsharing networks are some other examples.

605 Efficient fleet rebalancing through the relocation of shared vehicles to balance supply and
606 demand is a challenge for service providers, both in one-way (Yang et al., 2021) and free-
607 floating (Willing et al., 2017) carsharing services. To conquer the imbalanced distribution of
608 vehicles' supply, user-based (Di Febbraro et al., 2019), operator-based (Santos and de Almeida
609 Correia, 2019), or a combination of user-based and operator-based relocation strategies can be
610 applied (Huang et al., 2020). Each of these strategies entails several challenges, and the
611 replacement of combustion engine vehicles with EVs adds more operational challenges due to
612 the range limitation of EV batteries. For instance, aiming at the maximization of the carsharing
613 service provider's profit, Huang et al. (2020) compared the efficiency of a user-based and an
614 operator-based relocation system in a one-way electric carsharing platform through the
615 development of three mixed integer nonlinear programming models, taking SOC of EVs into
616 account. Di Febbraro et al. (2019) proposed a two-stage optimization model to optimize the
617 alternative destinations suggested to users and also to maximize the operator's profit in a one-
618 way carsharing system with a user-based relocation strategy. A bilevel nonlinear mathematical
619 programming model, considering the vehicle fleet, prices, relocation operations, and the choice
620 of travelers between carsharing and private cars, was proposed by Lu et al. (2021) to maximize

621 the carsharing service provider's profit and minimize the overall travel cost for travelers.
622 Furthermore, a proactive operator-based relocation policy based on Markov chain dynamics was
623 introduced by Repoux et al. (2019), which applies reservation information for the prediction of
624 stations' future states and aims to maximize the number of accepted user requests.

625 In addition to the optimization models, simulations have been considered by researchers to
626 incorporate their analysis in a realistic operational environment. For instance, Boyacı et al.
627 (2017) developed an integrated multi-objective mixed-integer linear programming optimization
628 and discrete event simulation framework to deal with the operational decisions of vehicle and
629 personnel relocation in a carsharing platform, which allows reservation by users in advance.
630 Also, an agent-based model was developed and applied to the city of Lison by Martínez et al.
631 (2017), considering the complex supply-demand relationship, maintenance operations,
632 relocations, and reservations. The supply-demand imbalance has also been analyzed through
633 other methodological approaches, too. In this regard, Willing et al. (2017) developed a spatial
634 decision support system based on data from a carsharing service provider in Amsterdam, which
635 contributes to lowering the risk of supply-demand imbalance in free-floating carsharing systems
636 through variable trip pricing.

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

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

648 **3.3.4. Cluster 4: Technological advancement towards deployment of shared** 649 **autonomous vehicles and MaaS**

650 Vehicle sharing, electrification, and automation are three revolutions (so-called “3-R”) on track
651 in urban transportation (Fulton, 2018). Although the earliest carsharing experiences date back to
652 more than seven decades ago (Shaheen et al., 1998), these services are still an emerging
653 phenomenon (Münzel et al., 2018) and represent a small share of trips only in some urban areas
654 (Fulton, 2018). Given the growing attention of policy-makers to shifting towards electric and
655 green transportation to respect the environment (e.g. EC (2009) and EC (2014)) and the recent
656 advances in EVs’ battery technologies, incorporating EVs into carsharing programs and
657 providing electric carsharing services has been expanded quickly around the world but it has not
658 yet become mainstream (Hu et al., 2019). Moreover, full automation of vehicles is the next major
659 evolution in urban mobility and autonomous vehicles (AVs) (also called driverless or self-
660 driving vehicles) are anticipated to bring fundamental shifts in urban transportation systems
661 (Mourad et al., 2019). The arrival of AVs on the one hand is argued to make driving cheaper,
662 safer, faster, and greener, reducing traffic congestion and environmental impacts reduced; and on
663 the other hand, is increasing concerns on inducing additional driving that can result in offsetting or
664 overwhelming the positive effects (Naumov et al., 2020). Although AVs are still being tested,

665 they are expected to be an integral part of future transportation within the next few decades
666 (Vosooghi et al., 2020) and serve as shared autonomous vehicles (SAVs) within the carsharing
667 scheme. Future SAVs are likely to be electric (Vosooghi et al., 2020; Zhao et al., 2021) and
668 hence, these emerging technological advances can help make the carsharing systems more
669 efficient and environmental-friendly.

670 Several recent studies have focused on the development of AVs, SAVs, and shared autonomous
671 electric vehicles (SAEVs) and have analyzed their relevant implications. For instance, Zhao et al.
672 (2021) provided an optimization model for a near-optimal design of charging station location of
673 SAEVs; Chen et al. (2016) suggested a simulation model to examine the operation of SAEVs
674 under various vehicle and infrastructure scenarios; and Vosooghi et al. (2020) investigated the
675 impact of charging infrastructure on the performance of SAEVs. Also, Li and Liao (2020)
676 developed an optimization model to moderate the supply and demand of SAVs. Another group
677 of researchers, such as Wadud and Chintakayala (2021), Haboucha et al. (2017), and Nazari et al.
678 (2018), considered user preferences and the willingness to own an AV or use an SAV.

679 However, technological advancements linked with carsharing in the urban transportation system
680 are not limited to the electrification and automation of vehicles. Mobility as a service (MaaS) is
681 an emerging concept in this regard, which aims at breaking the determining role of car ownership
682 (Becker et al., 2020) by matching the travel needs of an individual with a tailored mobility
683 package (Storme et al., 2020) that includes various mobility services such as carsharing, ride
684 sharing, bike sharing, car rental, taxi services, and public transport. MaaS integrates payment and
685 routing across several transport service providers on a single platform (Reck and Axhausen,
686 2020) and includes a real-time journey planner (Storme et al., 2020). Although this digital

687 interface increases the efficiency of passenger transportation networks (Esztergár-Kiss and
688 Kerényi, 2020), it is suggested that it should be regarded as a complement of private car use
689 rather than a substitution for it (Storme et al., 2020). Despite considering carsharing as a model
690 of transport in some recent studies on developing MaaS (e.g. Esztergár-Kiss and Kerényi (2020),
691 Brezovec and Hampl (2021), and Reck and Axhausen (2020)), research on MaaS plans is still in
692 its infancy and needs to receive more attention from the researchers in the field of shared
693 mobility.

694 **4. Implications for research: Directions for future studies**

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

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

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

702 **4.1. Developing a long-term sustainability assessment framework**

703 The actual impact of the entrance of shared-mobility service providers, such as carsharing
704 platforms, to the market on transitioning towards sustainability is still under discourse. On the
705 one hand, carsharing can provide benefits, such as lower individual transportation energy use and
706 greenhouse gas emissions (Chen and Kockelman, 2016; Namazu and Dowlatabadi, 2015). On

707 the other hand, despite the positive aspects, carsharing can intensify some urban mobility
708 challenges, such as increased road congestion in terms of both intensity and duration (Diao et al.,
709 2021), and car dependency (Boons and Bocken, 2018). This dilemma, which is also addressed by
710 Shams Esfandabadi et al. (2020), requires to be analyzed through a framework based on a
711 systems thinking approach, as a proper lens to look at the long-term effects of these services
712 from the sustainability assessment point of view. To the best of the authors' knowledge, a
713 systems thinking approach to monitor and capture the sustainability implications of carsharing
714 services as a whole for urban transport in long term is lacking in the literature. In this regard,
715 developing assessment frameworks and applying simulation models with a macro level of
716 analysis, such as System Dynamics, is highly recommended for future studies to better assess and
717 analyze the implications of carsharing and plan to incorporate carsharing services into the urban
718 transport system to move towards sustainability.

719 **4.2. Drafting inclusive marketing and training plans, and designing effective incentives**

720 For a successful and sustainable diffusion of alternative technologies in transportation systems,
721 keeping marketing programs and subsidies in place for long periods is essential (Keith et al.,
722 2020; Struben and Sterman, 2008). This is while unawareness of people about carsharing has
723 been mentioned as the main reason for a low diffusion of carsharing in some areas, such as in
724 Italy (Rotaris, 2021). In this regard, a holistic plan to sufficiently encourage the public to use
725 carsharing services seems to be required in many parts of the world, as the deployment of
726 carsharing can accelerate the transition to sustainable urban mobility if accompanied by proper
727 policies. Therefore, more research and investigative explorations are needed to fill this research
728 gap, in particular in the following research directions: (i) formulating effective marketing

729 strategies to increase the familiarity of people with carsharing and subsequently, increase the
730 share of carsharing services from the whole urban transport; (ii) proposing innovative incentives
731 for citizens as potential users, intermediary companies as service providers, and local
732 government and relevant authorities as supporting stakeholders; (iii) conducting more context-
733 sensitive research to customize the evaluation frameworks of different potential carsharing users
734 characteristics in various geographical regions; (iv) designing effective plans to prevent switches
735 from public transport to carsharing, and at the same time, increase switches from private cars to
736 carsharing; and (v) formulating training programs for different segments of the population to
737 increase knowledge about the potential role of carsharing in developing a sustainable society.

738 **4.3. Analyzing the role of carsharing in achieving Sustainable Development Goals**

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

746 The emergence and development of carsharing platforms within the mobility system is notably in
747 line with SDG 12, referring to ensuring sustainable consumption and production patterns.
748 However, the expansion of carsharing services can potentially affect other SDGs and their
749 associated targets. Carsharing literature contains a vast amount of research on the energy
750 consumption and environmental effects of these services that are mostly linked with SDG 7

751 (affordable and clean energy) and SDG 13 (climate action), while carsharing research taking
752 other SDGs into account is still in its infancy stage. For instance, social exclusion issues such as
753 gender inequality in carsharing have been addressed in the research conducted by Alonso-
754 Almeida (2019) and Singh (2020), although no direct implications have been elaborated for any
755 specific SDG in their research. In other words, the explicit and implicit effects of carsharing
756 services on the achievement of SDGs are still blurred, calling for more comprehensive research
757 and developments to foster the progress towards sustainable development. In this regard, some
758 potential avenues for future carsharing research towards achieving SDGs could be based on (i)
759 developing initiatives to reduce inequalities and avoid social exclusion in using carsharing
760 services, corresponding to SDG 5 and SDG 10, (ii) promoting sustainable consumption patterns
761 and plans to increase economic growth, corresponding to SDG 8 and SDG 12, and (iii)
762 contributing to building sustainable cities and communities, corresponding to SDG 11.
763 Moreover, since the achievement of the SDGs has been affected by the COVID-19 pandemic
764 (Ameli et al., 2022; Ranjbari et al., 2021b), a potential avenue for future carsharing research
765 could be evaluating the long-term and short-term effects of the pandemic on the achievement of
766 SDGs related to the urban mobility.

767 **4.4. Developing circular economy indicators and circularity measurement system within**
768 **the shared mobility domain**

769 Transitioning from a linear economy to a circular economy, as a tool to promote sustainable
770 development has brought economic, environmental, and social benefits to societies at the local
771 and global scales (Shevchenko et al., 2021). Carsharing services through providing more
772 utilization of shared vehicles instead of privately-owned vehicles can potentially support the

773 transition towards a circular economy in the transportation system. In this regard, carsharing
774 services, as a potential alternative for personal cars, can decrease the demand for car ownership
775 and car manufacturing, resulting in less consumption of materials and resources as well as less
776 pollution and waste generated by car manufacturers (Shams Esfandabadi et al., 2020). As a
777 result, shared mobility services, in particular carsharing deserve to be put forward as a potential
778 solution to implement the circular economy strategies in urban mobility systems.

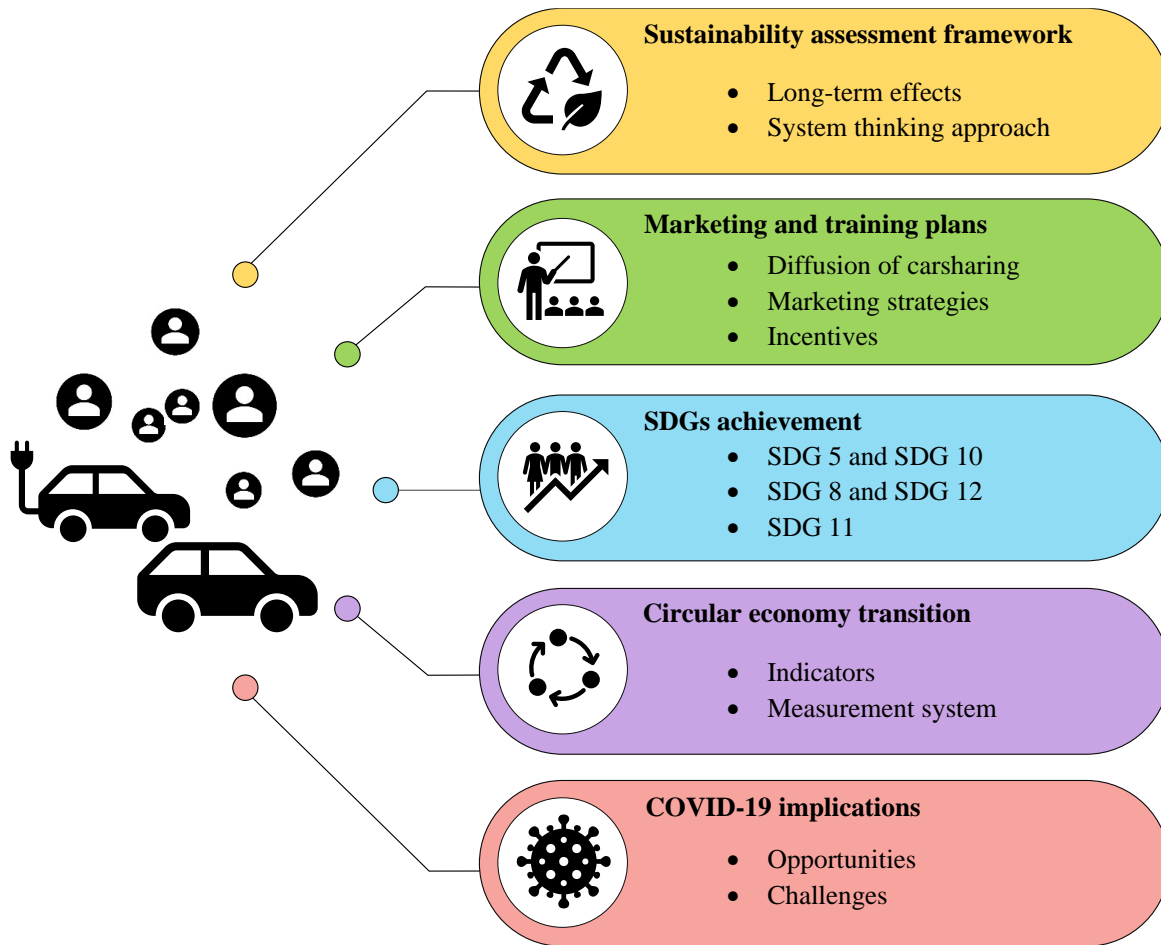
779 Nevertheless, although the potential of shared mobility services vs. privately-owned vehicles to
780 more effectively keep the current vehicles in use and at value seems to be in line with the circular
781 economy principles, the research in this area is very limited. In the same vein, the literature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

792 **4.5. Assessing the implications of the COVID-19 pandemic for carsharing**

793 The impacts of the COVID-19 pandemic on different aspects of human lives are undeniable
794 (Ranjbari et al., 2021c). Restrictions on the mobility of people during the pandemic and the

795 requirement of keeping a safe distance from others changed the behavior of people in using
796 various modes of transportation during this period. Therefore, long-term impacts on the transport
797 sector in the post-pandemic era seemed likely, and it was projected that the new normal situation
798 after the pandemic could provide an opportunity to move towards a more sustainable transport
799 sector (Zhang and Zhang, 2021). Nevertheless, carsharing was identified as a sector seriously
800 suffering from the outbreak of the COVID-19 pandemic (Garaus and Garaus, 2021).

801 Despite a significant amount of research on the changes caused by the lockdowns and mobility
802 restrictions on the overall urban transportation (Andara et al., 2021; Ravina et al., 2021; Zhou et
803 al., 2021), limited research in the carsharing domain has pointed to changes borne by these
804 services during the pandemic, and opportunities and threats in the normal future after that. For
805 instance, concerning the pandemic period, Garaus and Garaus (2021) analyzed the consumers'
806 intention to use carsharing during the pandemic in Germany; Alonso-Almeida (2022) studied the
807 drivers and barriers, as well as the usage and advantages of carsharing during the pandemic; and
808 Turoń et al. (2021) studied the required aspects to be considered in the context of a pandemic
809 when modeling and optimizing energy services for electric carsharing, as a part of electric shared
810 mobility services. Also with regard to the movement towards decarbonization of the transport
811 sector in the new normal after COVID-19, Zhang and Zhang (2021) analyzed the reduction
812 potential of CO₂ emissions by 2060 as a result of change in the lifestyle of the people and the
813 usage of transport modes including carsharing. Therefore, a comprehensive overview of the
814 short-term and long-term implications of the pandemic for the usage of carsharing is still lacking.
815 As a result, decision-makers need to take potential scenarios and policies related to the COVID-
816 19 outbreak into account to better manage the diffusion of carsharing towards a sustainable
817 transport system.



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

820

5. Concluding remarks

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Carsharing services with the aim of reducing private car ownership have been increasing in

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recent years. A huge amount of research has been carried out on carsharing considering different

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aspects from business models and operational challenges to sustainability aspects and travel

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behavior, leading to fragmented literature. As the first attempt in the literature, our research

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provided a systematic bibliometric analysis on carsharing research, covering a total of 729 peer-

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reviewed journal articles in WoS that were published by the end of June 2021.

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

836 Based on the provided inclusive map of the carsharing research background to date, five main
837 research gaps were identified and proposed for future studies. First, since the actual impact of
838 carsharing services on transitioning towards building sustainable cities is still unclear,
839 developing a long-term sustainability assessment framework for carsharing activities could be a
840 promising direction for further studies. Second, in order to increase the awareness and familiarity
841 of people with carsharing services, developing inclusive marketing and social exposure plans to
842 encourage all actors could help better promote carsharing usage more sustainably. Third,
843 carsharing is basically developed in line with SDG 12 and can affect other SDGs of the UN's
844 2030 Agenda for Sustainable Development. Analyzing the role of carsharing in the achievement
845 of different SDGs and their targets could support more effective planning to step towards
846 sustainable cities and communities. Fourth, literature on carsharing lacks circular economy
847 indicators and circularity measurement systems to assess the circularity of the activities taking
848 place in relation with carsharing, which deserves to be considered in future research. And finally,
849 despite the significant implications of the COVID-19 pandemic for urban transportation systems,

850 studies on the effects of pandemic on the future of carsharing is scarce, which can be further
851 supported by researchers in future studies.

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

858 **Acknowledgment**

859 The authors acknowledge financial support received from Energy Center Lab, Politecnico di
860 Torino in Italy for this research.

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