Transportation Mobility During COVID-19: A Systematic Review and Bibliometric Analysis

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ABSTRACT

The COVID-19 pandemic has tremendously affected global transportation mobility, presenting unprecedented challenges to transportation management. The ridership of public transit and ride-hailing services reduced drastically which transcended the inclination towards private vehicles. Furthermore, the pandemic drastically affected the travel pattern and transportation mobility of individuals due to the implication of various COVID-19 protocols. Despite majority of research gravitating towards traffic demand and mode choice modeling, the logical reasoning, and behavioral changes associated to the findings were sporadically studied. This study conducted a comprehensive review of 96 academic papers from reputable journals spanning January 1, 2020, to December 31, 2022, focusing on small-distance mobility in developed, developing, and underdeveloped nations utilizing the Scopus database. The review identified three major themes: “Impact on Ride-Hailing Services,” “Impact on Mode Preference,” and “Impact on Trip Purpose.” Each theme was subdivided based on keywords and key findings extracted using VOSviewer. The study revealed that the pandemic significantly affected ride-hailing services, leading to changes in demand, usage, service, and safety measures. Mode preference saw a shift towards private vehicles due to safety concerns. The study underscores the long-term implications of the pandemic, emphasizing recovery strategies for ride-hailing services and mode preferences post-pandemic. It highlights the need for sustainable transportation policies, advocating for enhanced public transportation systems, promotion of active travel modes, and addressing socioeconomic disparities in mobility patterns. Ultimately, the findings illuminate the paradigm shift in travel behavior, mode choices, and trip purposes, emphasizing the imperative for resilient transportation strategies in the face of future disruptions.

Keywords: COVID-19, Transportation Mobility, Bibliometric Analysis, Text Mining, Travel Patten, Travel Behavior
1. BACKGROUND

Transportation mobility around the globe was significantly hampered by the COVID-19 pandemic, which had unprecedented effects on various aspects of society, including social activities, the economy, and daily lives. This resulted in increased car ownership, inequalities due to unemployment and poverty worldwide. Furthermore, it was found that the ridership of public transit and ride-hailing services decreased by 70-90% and 60-70% respectively in major cities around the globe (Wang et al. 2022). Hence, the shift towards private vehicles, and active modes of transportation was prominent (Bustamante, Federo, and Fernández-i-Marin 2022; Padmakumar and Patil 2022). For this reason, many operators, micro-mobility, and carpooling players halted their services during the pandemic, which directly affected the traditional automotive section that had projected 7.5 million fewer vehicles in 2020 (McKinsey & Company 2020).

In the early stages of COVID-19, people strongly responded to the threats imposed by the pandemic and avoided unnecessary travel, which led to the decline of all major transportation uses (Shakibaei et al. 2021). Again, the need for travel was noticeably reduced by encouraging work from home, distance education, job dismissals and abandonment of all social gathering. Since these implications occurred in various phases of the pandemic, the deviations in travel pattern and transport mobility among the phases were prominent, specifically for commuting and social/recreational/lesure trips. In many countries, traffic was reduced dramatically across the weeks and during the lockdown period this volume declined significantly (Zixuan and Raphael 2021). Therefore, the pandemic has immensely affected how people travel, their mindset, and their modal choices, including the use of private vehicles, public transportation, and active modes. This has also played a delicate role in advocating the decrease of environmental pollution from traveling.

Although most studies were skewed towards traffic demand and mode choice modeling (Benita 2021), the logical reasoning, and behavioral changes behind such outcomes and decisions were undermined. Therefore, a comprehensive literature review is crucial to delineate the current understanding and explorations associated with user behaviors in transportation mobility during and after COVID-19 in a global manner. Hence, this study aims to explore the literature gaps and point out behavior change, mobility changes, and their holistic impacts on different study themes through a rigorous literature review. The study has explored previous papers that focused on small-distance mobility and have refrained from long-distance mobility modes.

2. METHODOLOGY

Literature on COVID-19, mobility, and transportation was utilized for this research, from the leading citation database: Scopus, which sources index from high-quality peer-reviewed publications and covers a broad range of literature topics. The bibliographic record and full-text articles were retrieved from Scopus database, and only the English language publications from peer-reviewed journals which were published between of January 1, 2020, to December 31, 2022, were considered. The search was narrowed down using the keywords COVID-19, public transport, travel behavior, and mobility in titles, abstracts, and research citations.

By 2022, COVID-19 had affected the entire world, from underdeveloped and developing countries to developed countries. Hence, studies from all these countries were considered, and 475 studies were primarily filtered, which were again screened by subject areas of Social Science, Engineering, Decision Science, Mathematics, and Psychology. Finally, 96 articles were selected for the analysis. These articles were published in 36 reputed journals, where the top three journals
were Transport Policy with 21 publications, Sustainability with 13 publications, and Transportation Research Part A: Policy and Practice with 10 publications. All the journal articles are presented in **Figure 1**.

![Figure 1: Articles from different journals considered for detailed review and analysis](image)

**Figure 1** Articles from different journals considered for detailed review and analysis

In the second phase of this research, VOSviewer, a text mining tool was utilized to identify certain themes based on the theme dominance, obtained from the Keyword Co-occurrence Network (KCN). The text-mining feature of VOSviewer was employed to extract keywords from citations, abstracts, and titles, which then created a two-dimensional co-occurrence network. Based on outcomes of keyword analysis and systematic review, three emerging themes- ride-hailing services, mode preference, and trip purpose were explored in depth. The overall workflow of the research is illustrated in **Figure 2**.
The themes were divided into subthemes based on keywords and key findings presented in Table 1. Afterward, the papers were systematically reviewed. Finally, various bibliographic features like location (country), study methodology, the research timeline, trip purpose, analyzed modes, mode preference, and socioeconomic features, were tabulated using Microsoft Excel and assessed using tools like Sankey diagram, topic modeling analysis in Python, and keyword image, to carefully assess a wide range of concerns.

3. RESULT DISCUSSION

3.1 Bibliometric Features

Among the 475 primary selected papers, 96 papers from 36 academic journals were retained for systematic literature review. 69.8% of the papers conducted research during 2021, followed by 2022, and the least number of papers during 2020. This pattern coincides with the fact that by 2021, the pandemic had its highest infection rate and this started to decrease during 2022 (Wang et al. 2022). Unfortunately, 216 countries or territories were affected by this disease. Subsequently, in the 96 papers, research was conducted in 35 countries, where the USA was one of the most affected countries, showing the highest numbers of research (16 papers), followed by Spain (7 papers) and India (6 papers) in second and third positions respectively. Again, 8 papers focused on worldwide coverage, while 5 concentrated on European and other selected countries since lockdowns in countries globally started on March 2020 (except China) owing to the uncontrolled outbreak (Figure 3). The distribution of papers in different countries around the globe is illustrated in Figure 4.
This dispersal was further analyzed through a sankey diagram (Figure 5) to illustrate the distribution of the selected papers across different countries and highlighting their contribution to each focal theme (Table 1). The size and position of the sankey’s segments correspond to the number and significance of papers from each country, where the USA had a key contribution in all the focal themes, followed by Canada and Spain. However, India, Switzerland, Iran, and Sweden, among others, lacked the ride-hailing theme. Furthermore, other countries focused on either a single theme that had a physical effect on their society or was expected to have a foreshadowing effect soon.
Interestingly, 44.8% of the papers were either interviews, survey-based, or hybrid, whereas the rest of the papers used secondary data for their analysis. In the interview/survey-based papers, 31 pieces of literature collected their data online, and only 9 papers physically considered the pandemic situation. Web-based interviews/surveys usually provide a wide range of convenience and respondents even in distant places. However, this could serve as the nesting ground for various biases, including self-reporting and response & non-response biases (Awad-Núñez et al. 2021), which decreased the analysis accuracy. On the other hand, all these papers conducted their research through general evaluation of reports (highest), model building, standard statistical analysis, case study, and literature reviews presented in Figure 6 and primarily focused on all transportation modes (56.3%), followed by ride-sharing services and public transit systems that were the most affected (Figure 7).
The abstracts were analyzed by generating a comparison diagram in Python through topic modeling analysis, a powerful tool that is used in bibliographic analysis to uncover and identify thematic patterns. The diagram shows the result for the top 50 words and their frequency (Figure 8). The Natural Language Toolkit’s (PLTK) Punkt tokenizer was leveraged using Python for sentence splitting and the stopwords list to preprocess and clean the textual data from the 96 papers. The top three words transport, COVID, and mobility validate the bibliographic study. Moreover, this also implies the importance of travel behavior, lockdown policies, and ridesharing, among others. However, this analysis is not enough to get a clear picture. Hence, Keyword Co-Occurance analysis was done to get a better theme and sub-theme analysis.
Figure 8 Frequencies of the top 50 most used words in article abstracts

Keyword Co-Occurrence

Figure 9 illustrates the co-occurrence of the keywords from the 96 papers that were generated through text mining using VOSviewer. The generated illustration showed nine lines of research depicted in nine distinct colors, where the light blue color, with the broadest area, describes the effect of Covid 19 on micro-mobility, trip purpose, and public transportation. The straw color represents the effect of travel behavior on public perception, shared mobility, and sustainable transportation. The green color illustrates the pandemic’s impact on travel behavior, traffic congestion, and lockdown policies. Subsequently, red, pink, orange, and purple represent the mobility effect on the urban setting, bike sharing, and mobility habits.

Therefore, based on the cluster areas, the findings were brought under three common themes: the impact on ride-hailing services, mode preference and trip purpose. A keyword image was also generated based on the text mining data which depicts the intensity and dynamicity of keywords (Figure 10), to validate the finding in VOSviewer and topic model analysis. Next, the subthemes were prepared based on the keywords and key findings which are presented in Table 1.
Figure 9 Keyword Co-Occurrence of 96 Literatures.

Figure 10 Keyword Diagram from Text Mining.
## TABLE 1 Theme and sub-theme distribution of 96 papers

<table>
<thead>
<tr>
<th>Major Theme</th>
<th>References</th>
<th>Sub-Theme</th>
<th>Keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact on</td>
<td>(Alonso-Almeida 2022; Braut, Migheli, and Truant 2022; Loa et al. 2022;</td>
<td>Change of Demand and Usage</td>
<td>Autonomous public transport, autonomous vehicles, bicycles, bike sharing, COVID-19, case studies, demand responsive transport, diseases, emerging mobility, epidemic and pandemic, human and behavioral factors, information and communications technology (ICT), instrumental variables, literature review, ordinal logistic regression, public transportation, ridership, Seoul, sharing anxiety, smart cities, smart city, social factors, transportation policy, travel behavior, travel characteristics, urban form, urban mobility, urban planning</td>
</tr>
<tr>
<td>Ride Hailing</td>
<td>Song et al. 2022; Paul et al. 2021; Awad-Núñez, Julio, Gomez, et al. 2021;</td>
<td>Rise of Micromobility</td>
<td>COVID-19, bike sharing system, causal inference, cycling, user perception, lockdown, active travel, e-scooter sharing system, transportation means, spatial coupling, travel behavior, Saudi Arabia, food purchases, spatiotemporal mean, urban greenway, micro-mobility, infrastructure intervention, mobility-as-service, natural experiment</td>
</tr>
<tr>
<td>Services</td>
<td>Coppola and De Fabiis 2021; Shaik, Hossain, and Rony 2021; W. Wang et al.</td>
<td>Shift in service offering and safety measures</td>
<td>Accident, car sharing usage, China, COVID-19, discrete choice modeling, generalized regret minimization, Heckman modeling, lockdown, ordered logit model, pandemic times, perception of risk, post-COVID-19 travel behavior, post-COVID-19 mobility, public transport, random regret minimization, random utility maximization, ride-sourcing, road safety, shared mobility, sharing mobility, smartphone, sustainability, travel equity, travel behavior, travel mode choice, urban infrastructure, perceived accessibility, sustainable transportation</td>
</tr>
<tr>
<td></td>
<td>al. 2022; D. Wang et al. 2021; Shearston et al. 2021; Xu, Chen, and Liu 2021; Kyongok 2021; Dolins, Wong, and Nelson 2021; Aparicio, Arsenio, and Henriques 2021; Q. Liu et al. 2021; Luan et al. 2021; Frank, Hong, and Ngo 2021; Molloy et al. 2021; Shokouhyar et al. 2021; Mouratidis, Peters, and van Wee 2021; Almannaa et al. 2021; Pase et al. 2020a)</td>
<td>Socioeconomic Disparities</td>
<td>Causal inference, coronavirus, COVID-19, demand forecasting, discriminative pattern mining, health impacts, high-speed rail, instrumental variables, interpersonal distancing, mobility habits, multimodality, order-preserving traffic dynamics, public transport, recovery, ride-sharing, smartphone, suburban rail services, sustainable mobility, train capacity, transport equity, transportation, transportation planning, perceived accessibility, public transportation</td>
</tr>
<tr>
<td>Major Theme</td>
<td>References</td>
<td>Sub-Theme</td>
<td>Keywords</td>
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<td>-------------</td>
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</tr>
<tr>
<td>Impact on Mode Preference</td>
<td>(J. Wang et al. 2022; Monterde-i-Bort et al. 2022; Awad-Núñez, Julio, Moya-Gómez, et al. 2021; Bustamante, Federo, and Fernández-i-Marin 2022; Padmakumar and Patil 2022; Luo et al. 2022; Y. Wang et al. 2022; Manzira, Charly, and Caulfield 2022; He et al. 2022; Hörcher, Singh, and Graham 2022; F. Wang, Ge, and Huang 2022; Baig et al. 2022; Bohman et al. 2021; Bagdatli and Ipek 2022; Shortall, Mouter, and Van Wee 2022; Gkiotsalitis and Cats 2021; König and Dreßler 2021; Zhou, Liu, and Grubesic 2021; Chang, Meyerhoefer, and Yang 2021; Dogra et al. 2021; Rodríguez González et al. 2021; Teixeira, Silva, and Moura E Sá 2021; Parashar and Cheriyan 2021; Lei and Ozbay 2021; Thombre and Agarwal 2021; Zhang et al. 2021; Brough, Freedman, and Phillips 2021b; Shaer et al. 2021; Chan et al. 2021; Hasselwander et al. 2021; Sahraei, Küşkapan, and Çodur 2021b; Dostál et al. 2021; Corazza and Musso 2021; Qian and Ukkusuri 2021; Munawar et al. 2021; Naletina 2021; Sahraei, Küşkapan, and Çodur 2021a; Jiao and Azimian 2021; Becken and Hughey 2021; Tarasi et al. 2021; Timokhina et al. 2020)</td>
<td>Personal Vehicles</td>
<td>Active travel, anthropogenic air pollution, Bluetooth traffic monitoring system, COVID-19, disease prevention, equity, generalized linear mixed effects model, Google and Apple mobility data, greenhouse gas emissions, healthy cities, Indian cities, mobile device data, mobility, mobility-shift, multidisciplinary, post-pandemic, prediction, public transport, resilient public transport, smart card data, smart mobility, transport modes, transport policy India, transportation demand, travel behavior, travel modes, university students, transportation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Towards Public Transportation and Shared mobility</td>
<td>Air quality index, bluetooth traffic monitoring system, big data analysis, capacity management, commuting, case study, coronavirus, covid-19, covid-19 response, inequality, infection fear, longitudinal case study, mixed methods, mobility, mobility behavior, mobility change, mode shift, pandemic, prediction, public perceptions, public transit, public transport, public transport planning, public transportation, resilient transport systems, ridership, rural areas, safety-and-mobility trade-off, smart card data, smart mobility, social distancing, social equity, spatial compartmental model, sustainable, teleworking, travel behavior, transport policy, public transit, work from home, biking Barcelona, bike-sharing motivations, bike-sharing system, emergency, factor analysis, lockdown, lockdown city, bike usage, mobility, new normal, pandemic, probabilistic machine learning, propensity score regression discontinuity, quasi-experimental research, sustainability, tactical urbanism, transit, urban mobility, yellow taxi demand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Active Transportation</td>
<td>Active travel, biking Barcelona, bike-sharing system, built environment, central businesses district (CBD), corona, COVID-19, daily commuting, equity, generalized linear mixed effects model, google and apple mobility data, Indian cities, mobile device data, mobility, mode choice, pandemic, passenger transport, policy, probabilistic machine learning, public transport, social impact, sustainability, sustainable mobility, tactical urbanism, traffic psychology, transport policy, travel behavior, travel modes, quasi-experimental research</td>
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3.2 Impact on Ride-Hailing Services (RSS)

3.2.1 Changes in Demand and Usage

Shared-micro mobility services surged in demand to facilitate a disease-resilient transportation system during the pandemic. A study in Singapore found that the total ridership increased by 150%, suggesting that the bike-sharing systems were an important alternative when public transit services got restricted (Song et al. 2022). Furthermore, in Karachi, Pakistan, individuals with more than two family members who traveled less than seven miles likely preferred carpooling (Xu, Chen, and Liu 2021). Surprisingly, people with higher net monthly income continued to generate more shared trips during this time in Dhaka, Bangladesh (Paul et al. 2021). Unfortunately, sharing anxiety and willingness to share rides comes as a major obstacle (Dolins, Wong, and Nelson 2021) in ride sharing programs. In Seoul, South Korea, this decreased bike sharing and rentals drastically (Kyoungok 2021).

After the pandemic, there was a difference in travel demand recovery for different modes. For example, demand recovery was seen faster worldwide in private modes than in public transit or
shared mobility (Ciuffini, Tengattini, and Bigazzi 2023). A study in India found that for public transit and sharing mobility the demand dropped by 11% and 2% than the pre-pandemic time (Rankavat et al. 2023). This finding corresponds with study results that show public transport being the least preferred mode that was studied in 24 papers, along with car/bike pooling (Figure 11).

Many of the studies were limited to the data from students (Braut, Migheli, and Truant 2022), and many respondents had cultural differences, where herd behavior and personal space were not taken into account (Dolins, Wong, and Nelson 2021). Limitations to demographic factors (Shearston et al. 2021; Almannaa et al. 2021), and socioeconomic factors like high and low-income neighborhoods (Pase et al. 2020a) decreased the accuracy to the models to predict behaviors and mode choice. However, factors like socioeconomic and psychological characteristics that affected user behavior in shared mobility were unnoticed in many cases.

![Figure 11 Comparison between most preferred and least preferred transportation modes.](image)

### 3.2.2 Shift in service offering and safety measures

As the impact of the pandemic started to diminish, service offerings in vehicles increased which improved the willingness to use vehicle-sharing services (Awad-Núñez, Julio, Gomez, et al. 2021). Users felt safer in this case and understanding user preference provided improved management in recovering demand (Alonso-Almeida 2022). However, a study in China found that travel mode choice shifted towards maximizing utility than fear of infection. There was an increase in using ride-hailing services for shopping and recreation activities considering the worsening economic conditions in China (Luan et al. 2021), which forced individuals to reassess their spending habits and divert to more cost-effective and convenient options. Again, a study in Toronto, Canada observed a gradual increase in ride-sourcing modality (Loa et al. 2022).

However, these studies in many instances underrepresented populations, for example, tech-savvy people were left out and only urban mobility was considered in some cases (Q. Liu et al. 2021; Loa et al. 2022). In addition, survey-based data might be highly conditioned by traumatic experiences that have been caused by socioeconomic uncertainty and health concerns (Awad-Núñez et al. 2021). This could have also under-represented many lower-income countries in understanding their ride-hailing services and so further research can be done in this regard.
3.2.3 Socioeconomic Disparities

There was a sturdy growth in the number of COVID-19 cases along with public transit trips, which indicated a cause-effect relationship (Wang et al. 2022). For example, a similar condition was found in areas outside Lisbon municipality and lower-income areas, revealing socioeconomic disparities in mobility during the COVID situation (Liu et al. 2021). Since higher-income people had alternatives to this type of sharing service, they were exempt from using ride-hailing services. In China, during this period, experienced older drivers who were active in duty and were highly respected depended more on ride-sharing services to make a living (Wang et al. 2021).

Policy implications based on these studies had specific limitations, for example, lacks causation insights and is limited to an ordinal variable (Wang et al. 2021). Artificial intelligence and Urban computing get easily influenced by data bias and data transparency (Aparicio, Arsenio, and Henriques 2021), raising ethical issues. Overall, studies never explored the long-term effect and recovery strategies for ride-hailing services in a post-pandemic scenario.

3.3 Impact on Mode Preference

3.3.1 Personal Vehicle Preference

The demand for bikes, private cars, and public transportation trips gradually decreased in popularity with the increased health concerns during the pandemic (Paul et al. 2021; Kyoungok 2021). Because of the lockdown, web-based activities substituted many of these trips (Mouratidis, Peters, and van Wee 2021). This caused a significant change in peak traffic volumes and work modes (Shearston et al. 2021). People quickly rehabilitated their preferences from public and shared means to foot and private vehicles when the infection rates got worse (Braut, Migheli, and Truant 2022). This might have been because of factors like reduced exposure risk, avoidance of crowded spaces, and more mobility. However, a study in Manhattan, USA contradicts this as private mobility decreased to 86% of their pre-covid demand during the pandemic (Rodríguez González et al. 2021).

Again, Figure 11 demonstrates the individual modes being preferred in 15 papers, which clearly indicates that socioeconomic stability plays a pivotal role in choosing modes. Furthermore, this also inclined with a study in Taipei, Taiwan, that saw an increase in motor vehicle ridership (Chang, Meyerhoefer, and Yang 2021). A finding in India found that for work trips, share for private modes and non-motorized transport were 10% and 4% higher among respondents after the COVID situation relaxed (Fallah Zavareh, Mehdizadeh, and Nordfjærn 2022).

In some studies, lower-income people with limited access to the web and modern devices were underrepresented (Wang et al. 2022; König and Dreßler 2021; Parker et al. 2021; Pase et al. 2020). Furthermore, other studies had limited sample sizes that had spatial and temporal limitations (Dogra et al. 2021; Rodríguez González et al. 2021), and few focused-on students only (Bagdatli and Ipek 2022; Braut, Migheli, and Truant 2022). In addition, processes like generalized linear mixed-effects (Padmakumar and Patil 2022) and regression models (Wang et al. 2022; Bagdatli and Ipek 2022; Shaer et al. 2021) are suitable for hierarchical data and accounting for random effects of mobility due to COVID. Similarly, Gaussian Process Regressors (González et al. 2021) require a relatively large amount of data to effectively model complex relationships. Therefore, these methods were employed by utilizing underrepresented lower-income groups, and socioeconomic stability of users, which is a recurring practice in many of the studies under this theme.
3.3.2 Towards Public Transportation and Shared Mobility

The pandemic situation highlighted the vulnerability of local public transit and the perception of safety (Corazza and Musso 2021). During the pandemic, public transportation usage in Turkey and Spain drastically decreased by 80% (Ali Sahraei, Kuskapan, and Yasin Codur 2021) and 95% (Gonzalez et al. 2021) respectively. In addition, because of the lockdown, there was a higher willingness to telework which further decreased this use (He et al. 2022). In Washington, lower-educated and lower-income people experienced declines in travel intensity, which affected their travel behavior even after the COVID period (Brough, Freedman, and Phillips 2021b). This solidifies the finding of this study that public transportation being the least preferred mode in most of the papers that discussed this topic (Figure 11). However, many countries have already started to bounce back with predictions going for higher travel frequencies related to public transport (Rankavat et al. 2023).

People were more inclined to bike sharing as motivation and the importance to maintain social distancing shifted in Libson, Portugal (Teixeira, Silva, and Moura E Sá 2021). Similarly, a study in Manhattan found that the impact of the shared mobility system was higher than the yellow taxi system, and the demand surged during the pandemic (Lei and Ozbay 2021). In Daejeon, Korea, bike-sharing increased both during and after the pandemic (Sim 2023). However, a study in Barcelona revealed that the liking to bike sharing decreased during the pandemic (Bustamante, Federo, and Fernández-i-Marin 2022), which is opposed to the study findings that found mobility sharing as one of the most preferred modes (Figure 11). This clearly indicates that certain demographic, socioeconomic and psychological factors address the choice of shared mobility, which needs to be focused on.

3.3.3 Active Mode of Transportation

In North Carolina, individuals preferred walking and driving over public transit during pandemic (Wang et al. 2022). On the other hand, a study in Dhaka found non-motorized vehicles 19.93% more popular (Braut, Migheli, and Truant 2022). Again, in the Netherlands, measures that encouraged cycling and walking also scored positively (Shortall, Mouter, and Van Wee 2022). However, in Greece, this effect varied for males and females as parameters like ecological footprint, safety measures, and personal safety mattered most for females. Cycling was more preferred there and 30% of their population already reduced car usage even after the pandemic (Tarasi et al. 2021). In Shiraz city of Iran, the average cycling and biking was still higher for Central Business District users after the pandemic (Shaer et al. 2021).

A similar case also occurred in many European countries as demand for active modes of transportation kept on increasing after the pandemic (Monterde-i-Bort et al. 2022). These outcomes align with the findings of this study. As active modes of transportation are one of the most preferred modality choices in 23 papers (Figure 11). However, the majority of the papers that discussed active modes of transportation relied on general evaluation and normal statistical analysis and had data limitations mentioned in the earlier themes. But factors that presented user behavior/personas were sometimes shadowed by traffic demand and policy mapping.
3.4 Impact on Trip Purpose

3.4.1 Mode Choice on Trip Purpose

For rigorous classification, trip purposes were clustered into three distinct types: 1) Mandatory Trips, 2) Maintenance Trips, and 3) Discretionary Trips (Loa et al. 2021). At the start of the pandemic in Brazil, there was a substantial reduction in working (Mandatory trips) and non-essential (Discretionary trips) trips. Results indicated that essential workers were nearly three times more likely than the general population to make a mandatory trip during this time. Discretionary trips more likely to be made by males in comparison to females (Dias et al. 2021). Again, in Zurich, Switzerland, maintenance trips like park and grocery visits increased, while discretionary trips decreased during the lockdown period. This observation coincides with the findings of this paper that revealed the occurrence of Maintenance Trips the most, with 12 papers focusing on this aspect.

It is noteworthy that Mandatory Trips experienced the most substantial decline during the COVID-19 pandemic. Findings of the study conducted by Rafiq et al. (2022) and (Pawar et al. 2021) concluded that the severity of COVID-19 had a more pronounced impact on workplace visits during the pandemic, which also affected the low-income workers. Discretionary trips had lower travel frequency by 92% in comparison to mandatory trips in India. The diverse choices made by users during the COVID-19 pandemic are presented in Figure 12.

3.4.2 Behavioral and Socioeconomic Effects

During the pandemic, discretionary trips were largely canceled due to lockdowns (Strömblad et al. 2021). For people with disabilities, their daily travels were significantly reduced by destination (Park et al. 2022). However, older adults preferred active modes of transportation during and after the pandemic to avoid social constraints and crowds in their trips (Shaer et al. 2021). In the USA, transit riders with lower incomes had reduced their trips significantly (Beneitez et al. 2021). Again, in Toronto, Canada, people were reliant on private vehicles rather than public transit for non-mandatory trips (Loa et al. 2021). Furthermore, there was a significant drop in trips based on travel purpose, infection fear, occupation, and household (Borkowski, Jaźdżewska-Gutta, and Szmelter-Jarosz 2021).

![Figure 12: Mode Choice preference in Percentage.](image_url)
4. POLICY RECOMMENDATIONS AND CONCLUSION

The objective of this research was to examine the alterations in transportation mobility and travel patterns due to the COVID-19 pandemic. The study adopted a systematic review and bibliometric analysis methodology which included rigorous literature review and text mining techniques. A total of 96 papers were selected based on keywords from the Scopus database for review and analysis. Afterward, the papers were divided into three major themes named as Impact on Ride-Hailing Services,” “Impact on Mode Preference,” and “Impact on Trip Purpose.” Based on keywords each theme was subdivided and text mining was utilized to extract the key findings. The study unveiled that the pandemic prominently impacted ride-hailing services. This impact eventually resulted in changes to demand, usage, service, and safety measures.

Shared-micro mobility services were an important alternative when public transit services got restricted and saw an increase in demand during the pandemic (Song et al. 2022). People in developing countries were observed to use this frequently (Xu, Chen, and Liu 2021; Paul et al. 2021). In countries where shared mobility declined, anxiety and willingness to share were the major obstacles. Several papers observed a preference for individual modes of transportation (Brezina et al. 2021; Corazza and Musso 2021; Luan et al. 2021; Loa et al. 2021; Thombre and Agarwal 2021; Xu, Chen, and Liu 2021; Dogra et al. 2021; Chang, Meyerhoefer, and Yang 2021; Braut, Miglieli, and Truant 2022; de Palma, Vosough, and Liao 2022; Padmakumar and Patil 2022; J. Wang et al. 2022) and various policies to reintegrate the public interest towards public transit were discussed in several papers (Bagdatli and Ipek 2022; Naveen and Gurtoo 2022; Gkiotsalitis and Cats 2021; Shaer and Haghshenas 2021; Parashar and Cheriyan 2021; Tarasi et al. 2021). It was seen that the severity of COVID-19 had a higher impact on workplace trips compared to non-workplace trips during the pandemic and saw the highest decline.

For sustainable cities, it was concluded that multimodal transportation is a superior vision compared to relying on any one specific mode, with telecommuting being an effective part of an infrastructure sustainable strategy (Benita 2021). Regarding bike infrastructure, recommendations for improved existing biking infrastructure were suggested in multiple studies (Bustamante, Federo, and Fernández-i-Marin 2022; Manzira, Charly, and Caulfield 2022; Pawar et al. 2021). Similarly, better walking infrastructure was advocated for in studies (Pawar et al. 2021; Manzira, Charly, and Caulfield 2022), and multinomial logistic models showed that walking route quality, intersection safety, travel distance (with a negative effect), CBD accommodation, and greenery of the built environment influence the utility of walking as a preferred travel mode (Shaer and Haghshenas 2021). Redesigned spaces were proven effective for improving physical distancing without compromising public safety (Gouda et al. 2021).

In the domain of public transportation, several papers found that low-income groups used public transit even during the pandemic (Bohman et al. 2021; Baig et al. 2022; Dias et al. 2021; Brough, Freedman, and Phillips 2021a; Parker et al. 2021; Loa et al. 2021; Aparicio, Arsenio, and Henrique 2021; Ding, Loukaitou-Sideris, and Wasserman 2022; Hörcher, Singh, and Graham 2022; Y. Wang et al. 2022). Thus, identifying key working destinations for low-income groups and implementing targeted solutions is recommended (Wang et al. 2022). To prevent traffic congestion and rebuild people’s interest in public transportation systems (PTS), various measures such as contactless travel, e-tickets, open-data sharing policies, contactless soap dispensers, wash basins, and division of stops into groups based on infection possibility were recommended in papers (Bagdatli and Ipek 2022; Tarasi et al. 2021; Naveen and Gurtoo 2022; Parashar and Cheriyan 2021). The centralized availability of passenger data, ramp metering, and limiting
passenger boarding were suggested for efficient PTS management (Gkiotsalitis and Cats 2021). Moreover, improving walking accessibility to stations was deemed essential for enhancing PTS usage (Shaer and Haghshenas 2021).

Maintenance trips witnessed a decrease during the pandemic but continued to occur (Li et al. 2021; Ton et al. 2022). Swift recovery of the number of maintenance trips necessitates strategies to manage them effectively (Wang et al. 2022). Establishing outdoor sites near residences to provide daily necessities was proposed to reduce the frequency of going out and minimize the potential risks of infection (Li et al. 2021). For ride-sharing services (RSS), understanding customers’ willingness to pay more for RSS and considering economic factors in service cost calculations were highlighted (Awad-Núñez et al. 2021; Pase et al. 2020). It was suggested to increase the number of electric bikes and explore the use of cargo bikes to enhance the utility of these services (Bustamante, Federo, and Fernández-i-Marin 2022; Manzira, Charly, and Caulfield 2022). Overall, the extensive array of policies and recommendations presented in this study provides valuable insights into the multifarious approaches adopted by governments and policymakers.

This study is a smallendeavour to comprehend the impact of COVID-19 pandemic on people’s travel behavior, modal choices, and travel patterns. Although this study is a synopsis of previous studies that analyzed the factors associated with transportation mobility, it did not consider the extreme shifts in travel behaviour at various stages of the pandemic. Furthermore, comparisons among the themes were not discussed in this research. Therefore, future studies can evaluate how COVID-19 has gradually altered transportation mobility by considering a timeseries analysis of the bibliographics.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: M. R. H. Bhuiyan; data collection: A. Basunia, A. Muttaqi, M.R.H. Bhuiyan, F.A. Badhon; analysis and interpretation of results: A. Basunia, A. Muttaqi; draft manuscript preparation: A. Basunia, A. Muttaqi, F.A. Badhon, M.R.H. Bhuiyan. All authors reviewed the results and approved the final version of the manuscript.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.
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