COVID

Article

Assessment of the COVID-19 Pandemic on Public Transportation Ridership: A Comparative Analysis of Six Metropolitan Areas in North America, the Middle East, Asia, and Africa

Nawaf M. Alshabibi

Urban and Regional Planning Department, College of Architecture and Planning, Imam Abdulrahman Bin Faisal University, P.O. Box 2231, Dammam 32251-7025, Saudi Arabia; nalshabibi@iau.edu.sa

Abstract

The COVID-19 pandemic has caused unprecedented upheaval to the worldwide transportation infrastructure and as such, has redefined trends in urban mobility. In the current research, the authors plan to compare six metropolitan areas, including Houston (Texas) and Chicago (Illinois), Singapore, Dubai (United Arab Emirates), Calgary (Canada), and Cairo (Egypt), to assess the effects of the pandemic on transit ridership during the period of 2018 to 2022. The monthly data provided by the official transit agencies was analysed using paired *t*-tests and correlation statistics to measure the change in the ridership and how they are related to population, urban area, and network length. The results are consistent, and the effects are a three-stage course shock, stabilization, and recovery, but as the rates of recovery are different to the governance, economic structure, and technological preparation. Digitally developed, high-income metropolises like Singapore and Dubai were a bit faster in recovery, and those that relied on cars like Chicago and Calgary showed prolonged declines. Cairo also exhibited resilience driven by necessity and did not decline because of institutional adaptation, but rather because of economic dependence. The paper suggests a three-part model of resilience, including governance, technology, and necessity, that explains these differences and how mobility systems can be changed in response to crises. These findings have both theoretical and policy implications for designing adaptive, equitable, and technology-enhanced transportation planning in the post-pandemic age.

Keywords: public transportation; COVID-19 pandemic; urban mobility; adaptive resilience

Academic Editors: Lawrence D. Hayes and Claus Rinner

Received: 13 May 2026
Revised: 22 June 2026
Accepted: 26 June 2026
Published: 21 July 2026

1. Introduction

In cities, the population has been growing tremendously over the past decades. According to the UN, the global population has grown by about one billion every decade between 1980 and 2020 and the population is likely to continue growing at a similar rate during 2025–2050 [1]. This population growth requires effective transportation services in the cities, which would be essential for economic growth, socialization, and accessibility of the municipal services. The transportation in the urban areas has become indispensable to the control of the daily commuting trends and accessibility to services that are crucial in the viability of urban living [2]. It includes every type of public or private transportation that people use for any purpose in cities. Since growth in population has limited mobility of personal vehicles, many nations have enhanced the public transportation infrastructure to ensure stable mobility.

The average number of the public transit journeys per capita in the thirteen large countries in 2015 was 142 km/year, with 246 km and 40 km reported in Japan and the United

 https://doi.org/10.3390/covid6070130

States respectively [3]. In January 2020, COVID-19 was identified and, after being declared a pandemic by the World Health Organization in March, governments introduced measures like physical distancing and capacity limits. One of the most affected industries was the public transportation since there was crowding in vehicles and stations. In 2020–2021, measures like quarantine, distancing, school closures, curfew, and compulsory wearing of masks were enforced by governments for public safety. These restrictions drastically reduced the use of public transportation. The pandemic had a contradictory impact on urban mobility: some researchers reported more frequent non-motorized transportation, decreased commuting time, and lower use of personal vehicle, whereas others found that travel costs were more expensive, and transit utilization dropped significantly. The scale of the drop was different depending on the cities, which caused financial shortages for transit operators. In Stockholm, sales of tickets decreased by 60 percent during the lockdowns, and in smaller towns in Sweden, by 40 percent [2]. In the Greater Sydney Area of Australia, the total commuter savings stood at USD 4.407 billion by May 2020 [4,5].

Although many studies have been conducted on short-term effects of the pandemic in certain regions, not many studies have compared the effects internationally and quantified the overall impact of the pandemic. The decrease in ridership is also a metric that helps predict any future disruption and implement measures to address the impact on the economy and operations. This study measures the variation in the number of people using public transportation in terms of the overall passenger boarding on average in one month by utilizing data of leading cities across the globe. It is a comparative study based on six cities, i.e., Houston (Texas), Chicago (Illinois), Singapore, Dubai (United Arab Emirates), Calgary (Canada), and Cairo (Egypt). They were chosen based on the high usage of transit before COVID-19, access to monthly ridership data (2018–2022), and geographic and economic diversity, which made these cities meaningful to compare internationally. This study does not use one baseline year but instead uses a year-to-year comparative approach (2018–2022) to identify both long- and short-term effects of the pandemic. An evaluation of the inter-annual variability has implications for policy makers, planners, as well as researchers who are formulating preparedness plans in the event of such a disruption. The paper is an extension of previous research and attempts to correlate ridership decline with three variables, namely, the average population, urban location served and the length of the entire transit system. These variables signify the potential demand, spatial accessibility, and transit supply—the important dimensions that determine ridership performance. Altogether, they give a holistic impression of demographic and infrastructural determinants influencing transit losses during the pandemic and aid in the modeling of other future global shocks. The paper is structured in the following way: the literature review provides the synthesis of the existing research on the effects of the pandemic on transportation; the sections describing the data, methods, and framework provide the information on the datasets and method of analysis; the case studies use year-to-year percentage changes and paired two-tailed *t*-tests in order to identify statistically significant changes in the pre- and post-pandemic ridership. The correlation analysis is used to determine the relationships between the decline in ridership and the city factors. The Results and Discussion sections are combined to allow immediate interpretation, and the Conclusion offers reflections and suggestions on future research and policies.

There are three main aspects of this study that the authors believe are novel and that they found missing from the existing literature when combined in a single study. First, this study is not a single baseline study but a year-to-year comparative study, applied across six metros on four continents, with a range of income levels and varying governance structures. Additionally, it presents explicit statistical testing of significance for each year-to-year transition, which is done by a paired *t*-test, not just descriptive percentage changes. This methodology enables the identification of the three-phase phenomenon (shock, plateau, recovery) in the empirical field, rather than by presumption. This study seeks to quantify the relationship between the magnitude of ridership decline and the structural variables at the city level, such as population, urban area and length of transit network, using correlation analysis. This provides a broad statistical context for the qualitative accounts of differential resilience previously reported in the single-city case studies. This study is rooted in transportation systems analysis but has direct implications for public health and epidemiological studies. As a proxy indicator of overall compliance with non-pharmaceutical interventions (NPIs) such as physical distancing, stay-at-home orders, and seating restrictions in transit, and as a possible epidemiological hotspot since transmission has been linked to crowded spaces in public transit [6,7], public transit ridership is of epidemiological concern. To further clarify this relationship, COVID-19 case incidence data for each of the six study cities were examined over the time frame 2020–2022, from publicly available epidemiological surveillance data from national public health agencies and the Johns Hopkins University Center for Systems Science and Engineering COVID-19 dashboard [8,9]. The analysis shows that Houston and Chicago had high numbers of absolute cases, but relatively high vaccination rates by 2021. Singapore and Dubai, on the other hand, implemented robust public health measures, such as widespread testing, contact tracing, and centralized quarantine systems, to keep the incidence of the infection relatively low as well. While there were distinct phases of the epidemic in other Canadian cities, the COVID-19 confirmed case numbers in Calgary appeared to follow a similar pattern; in contrast, Cairo had relatively low confirmed case numbers, which may reflect limited testing capacity rather than low levels of transmission. The differences in ridership reduction and recovery align fairly well with the differences in the amount of disease burden and the intensity of public health responses. This implies that, beyond transportation infrastructure, the epidemiological context contributes importantly to an understanding of intercity variations in transportation outcomes. The results thus complement the broader public health research on the links between population movement, adherence to NPIs, and the reduction in infectious disease transmission [10].

2. Literature Review

The impact of the COVID-19 pandemic on the different processes in the transportation sector is an issue that has been extensively studied across the globe. The effect on travel behavior has been investigated [4], employment in the transportation sector [11], modes of transportation shift [2], and changes in the travel time and cost of a personal transportation [4,12]. These studies also indicated the effect of the pandemic on the pattern of everyday mobility and accessibility within urban areas [11,13].

Many studies even registered beneficial effects in the transportation sector, which was mainly caused by the diminished travel demand, less congestion, and the increased use of non-motorized transportation. Studies of private car travel indicated that there were substantial changes in time spent traveling per day and time used to travel at peak hours. According to Hensher et al. [4], it was estimated that the average reduction was USD 4.4 billion/y in the generalized travel costs in Australia, the Greater Sydney Metropolitan Area (time, delay, and fuel costs). According to Munawar et al. [11], the operating expenditure on public and freight transportation had reduced by 80 percent and there was increased walking and cycling. On the same note, Chinese research studies have reported a major change toward non-motorized modes of movement like cycling and walking [13]. All of these findings suggest that restrictions, teleworking, and behavioral changes created a short-term environmentally positive effect and decreased congestion in most of the cities.

Conversely, adverse effects on transportation patterns and operations have also been reported. Study [2] found the reduction in public transportation ticket sales to decrease by 60% in large cities of Sweden, and 40% in small cities. According to [4], the number of workers who travelled to work either by use of a public or a private mode of transportation reduced significantly in Sydney because of the rising telecommuting. They also estimated the amount of revenue they would lose in terms of public transportation at about USD 0.74 billion annually. A different study in Australia showed that bus and subway use, recreational traveling and work trips fell as much as 46%, 23%, and 15.5%, respectively [5]. Although the cost of transportation per individual dropped, the total demand on the income of the transportation agencies was reduced, which posed a threat to the economic viability of the transit companies.

There was also evidence of severe effects in developing countries. In Lagos, Nigeria, the cost of transportation increased dramatically due to limited supply made by the reduced passenger capacity and distancing issues [12]. A similar study with 329 participants in Lagos has identified a significant association between pandemic restrictions and financial and social disruptions, 94.5% of the participants in this study reported an increase in the cost of traveling and a decrease in access to transportation [13]. These measures, though enhancing the safety of the people, affected the economy of the users as well as the operators negatively.

According to an analysis carried out by Xiao [14], 30 transit agencies in the United States and Canada found that most of them needed emergency federal grants to keep operating, which shows how great the loss of revenue due to declining ridership was. These results indicate that even developed transit networks were under extreme economic pressure. In a review of the international literature, Gkiotsalitis and Cats [15] found ridership reductions of between 70% and 90% in the cities of Beijing, Tehran, Singapore, Toronto and New York. Other gaps in their analysis included the lack of quantification of loss of ridership and behavioral response to crisis situation and it is this that demonstrated the need to conduct global comparative studies to improve preparedness and resilience of transit systems.

The pandemic also had an impact on employment and mobility trends in the transportation industry beyond ridership. Based on U.S. Census Bureau data in May-December 2020, Munawar et al. [11] discovered that employment in areas of transportation fell significantly. They suggested predictive models to project such alterations in the future crises depending on the demographic and occupational variables. Likewise, Tarasi et al. [16] studied the mobility in the Greek cities and found two pandemic periods, which had different traveling patterns. Age, gender, ownership of cars, and employment had an effect on the travel behavior, where 40% preferred to travel by private cars, 50 percent preferred to walk, and 10% preferred to ride bicycles. These findings demonstrate how individualized and low-risk modes of travel are becoming prevalent due to health and safety issues.

Altogether, the reviewed literature proves that COVID-19 influenced the transportation system in many aspects: it influenced the number of people who ride on the trains, the prices, the demand, and the employment, both in short-term behavioral changes and long-term structural issues. Regardless of the range of study, there is an essential gap: one common quantitative indicator of the impact of the pandemic on public transportation ridership in different urban conditions does not exist. The absence of comparative, data-based research raises concerns about the necessity of worldwide research correlating the loss of ridership with the demographic and infrastructural aspects. These relationships are important for building resilient, adaptive transportation systems that can survive global events that may occur in the future.

3. Materials and Methods

The overall goal of this study is to conduct a statistical analysis of the impact that the COVID-19 pandemic has had on mass transit in chosen urban settings. In particular, this study determines the effects on each of the cases, in six metropolitan areas: Houston and Chicago (United States), Singapore, Dubai (United Arab Emirates), Calgary (Canada), and Cairo (Egypt). This study is guided by three research questions:

- RQ1: Is public transportation ridership in each of the six selected cities different from the previous year (between 2018 and 2022), and are these differences statistically significant?
- RQ2: Is there a shared 6-city pattern of disruption, stabilization, and recovery, or is it different across cities and/or statistically significant?
- RQ3: Do average population, total urban area and total length of the public transportation network have an association with the magnitude of the pandemic-related reduction in ridership at the city level?

The research questions were tested under the null hypothesis of no statistically significant difference in ridership between paired years. The six cities were selected based on three major criteria: (1) having a modal share of public transit greater than 30 percent of total urban trips; (2) having complete and reliable monthly ridership records available from at least 2018 onwards (and in most cases, up to 2022); and (3) being sufficiently geographically and economically heterogeneous to be able to compare units globally, including both developed and developing cities. These criteria ensure that the chosen case studies include a variety of transit systems, demographic profiles, and policy environments, which will strengthen the findings and make them less context-specific.

The ridership data were collected through direct access to the official data from the public transportation authorities of each study area. the sources include METRO Houston (Texas), the Chicago Transit Authority (City of Chicago), SBS Transit (Singapore), Dubai Roads and Transportation Authority (RTA), Calgary Transit, and the Central Agency of Public Mobilization and Statistics (CAPMAS), Egypt [17]. The information was in the form of monthly passenger numbers between the years 2018 and 2022.

The aggregated data were then compared in order to identify changes in the ridership over the five-year period. The methodology framework included three main steps, namely: (1) acquisition and pre-processing of data, (2) statistical analysis, and (3) results interpretation.

In the first phase, monthly ridership data of each city was gathered, checked, and normalized by considering the differences in population and different reporting units. Descriptive statistics were calculated in the second step to find the percentage changes in the years before the pandemic (2018–2019) and during the pandemic (2020–2021) and recovery trends during the post-pandemic year (2022 where data were available).

The year-to-year comparison in the tables was calculated as:

$$\text{change t}(\%) = \frac{\text{Ridership}(\text{t}) - \text{Ridership}(\text{t}-1)}{\text{Ridership}(\text{t}-1)} \times 100$$

where Ridership $(\text{t}-1)$ is the ridership in month t of the previous year.

This approach controls for seasonal effects by comparing the same month across years.

Annual averages were computed from the monthly values. Two tailed *t*-tests were used to test the statistical significance of the changes in pre-pandemic and pandemic conditions. Also, Pearson correlation was used to investigate the connection between the extent of decline in ridership and major urban variables including average population, total urban area, and total length of the public transportation network.

Microsoft Excel 2021 and IBM SPSS Statistics 27 were used to carry out all the statistical calculations and visualizations. The selection of these tools was to guarantee proper management of high amounts of monthly data and at the same time provide reproducibility and transparency in analysis. A paired two-tailed *t*-test was applied to monthly ridership pairs (e.g., January 2019 vs. January 2020) to test for differences between pre- and post-COVID periods.

- Null hypothesis (H_0): No difference in ridership between the two years.
- Test statistic: t-value—measures the size of the difference relative to variability. A larger absolute t-value (e.g., $|t| > 2$ with 11 degrees of freedom) indicates stronger evidence against H_0.
- Significance level: *p*-value
  - $p < 0.05 \rightarrow$ Reject $H_0 \rightarrow$ the change is statistically significant (95% confidence)
  - $p \geq 0.05 \rightarrow$ Fail to reject $H_0 \rightarrow$ no detectable change (may be real or due to noise)

The *t*-test was chosen because the data are paired (same month, different years) and the sample size (n = 12 months) is relatively small. This method is standard in transportation impact studies [18].

4. Results and Discussion

4.1. Houston (Texas)

Houston lies in the state of Texas, United States. It is the fourth most populous city in the United States and the largest in the state of Texas, covering about 1659 km^2 and accommodating 2.39 million inhabitants. The railroad network of Houston is operated by the Metropolitan Transit Authority of Houston, connecting key activity centers and major urban corridors within the metropolitan area. The Houston METRORail network consists of three intersecting light rail lines: The Red Line running north-south from Northline Transit Center to Fannin South, the Green Line traveling east from the Theater District to Magnolia Park Transit Center, and the Purple Line connecting the downtown Theater District to the Palm Center Transit Center in the southeast [19]. This helps readers understand the physical layout and connectivity of the system whose performance is evaluated throughout the paper [18].

Houston faced a significant impact due to the COVID-19, with a huge number of confirmed cases. This epidemiological outbreak directly reduced the ridership of transportation. Before the pandemic, the ridership trends were stable in 2018–2019, which means that there was no seasonal or structural volatility.

The effect of COVID-19 on Houston's public transit system is clearly seen in Figure 1, as well as the system's performance improvement compared with other North American cities studied. Ridership remained consistent, with a slight increase from 2018 to 2019, reaching a monthly average of 1.4 to 1.9 million passengers in Panel A. There was a significant decline in 2020, with ridership decreasing from approximately 1.5 million in early 2020 to about 0.55–0.7 million during the busiest months of the lockdown (April–June). Monthly ridership began to show signs of recovery in 2021 and continued to do so in 2022, with ridership in 2022 being between 1.0 and 1.2 million, with some improvement, but still below pre-pandemic levels. The size of the changes is shown in Panel B. The 2019–2020 period (grey dashed line) shows sharp decreases, with values around −65% in April 2020. The recovery for 2020–2021 was positive and was adequate, ranging from +15% to +25% in most months. This steady rise continued during 2021–2022 (green dashed line) with improvements of +20% to +35%. Patterns in Houston are similar to the systemic shock in 2020, the plateau/partial adaptation in 2021, and the heterogeneous recovery in 2022 in the six cities. The impact on Houston was much greater, but not as longlasting, as in more transit-dependent cities such as Chicago. The quicker rebound is the result of increased vehicle ownership, decreased overall need for public transportation, decentralized governance, and adjustments made by METRO (e.g., prioritized routes, improved sanitation, digital ticketing, etc.).

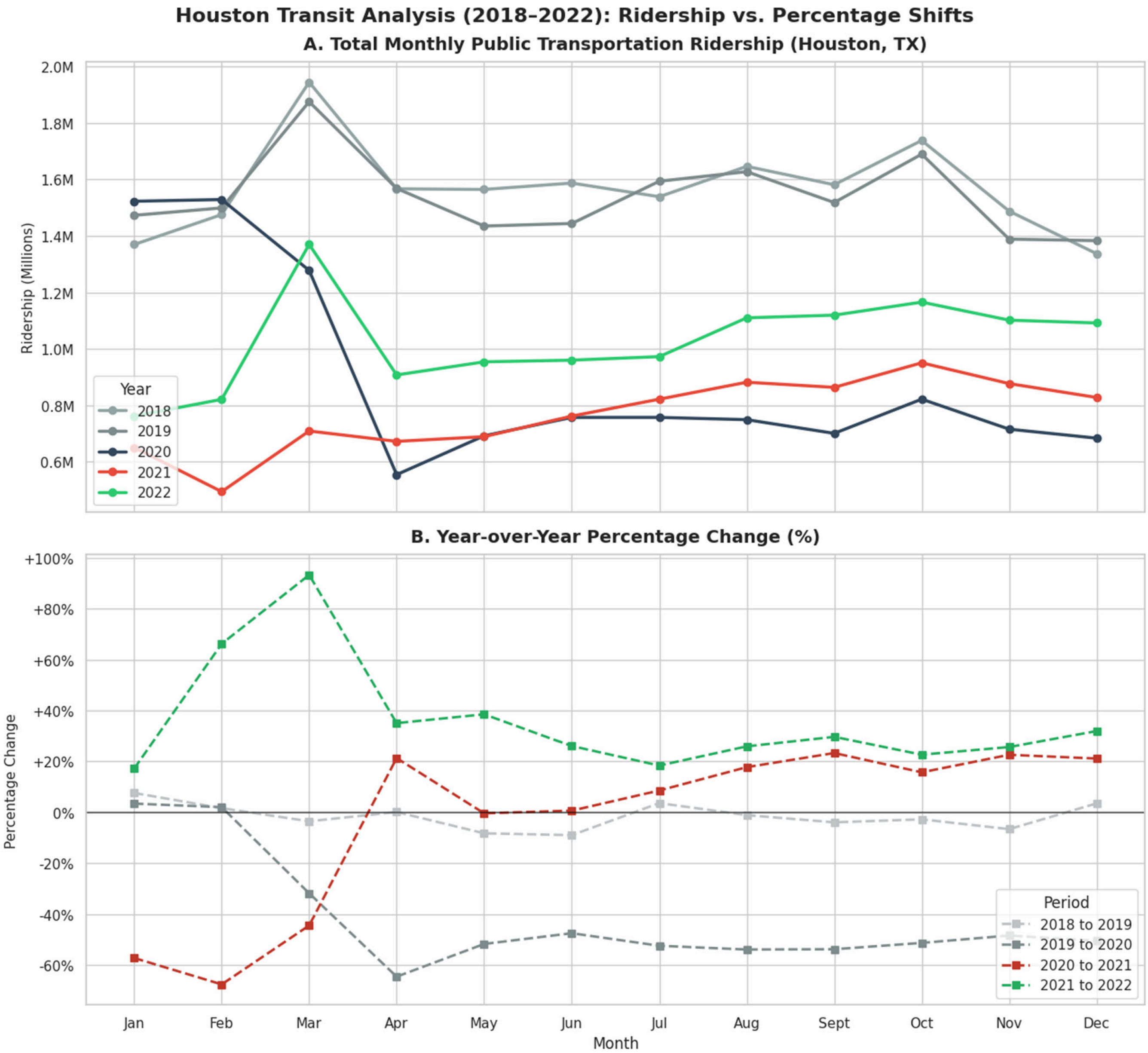

Figure 1. Comprehensive analysis of public transportation ridership in Houston, Texas (2018–2022). (**A**) Total monthly ridership (in millions) showing trends across the five-year period. (**B**) Year-over-year percentage change in ridership, highlighting the sharp decline in 2020 and moderate recovery in 2021–2022. Data sourced from METRO Houston.

Ridership patterns were due to behavioral and operational determinants. The first 64–66% contraction could be explained in terms of concurrent supply- and demand-side shocks, i.e., service suspensions, shortage of drivers and commuter risk aversion. The measures undertaken by the Authorities, which focused on providing priority routes, increasing sanitation measures, and offering micro-mobility services and application-based ticketing tools helped restore confidence in passengers. At the same time, hybrid work practices and the slow re-employment in the oil and service sectors helped to spur the recovery that was observed in 2022. Houston was found to have a relatively faster recovery rate when compared with other densely populated states like New York or Illinois because of a higher level of ownership of automobiles, lesser dependence on public transportation, and less restrictive forms of governance. Overall, the pandemic caused an immediate but temporary mobility crisis with ridership being partially restored in 2022. These results underline the paramount role of adaptive transit management, technological innovation, and recalibration of behavior that can be used to make urban transportation systems more resilient.

4.2. Chicago (Illinois)

Chicago is located within the state of Illinois and it is one of the densely populated metropolitan areas in the entire United States and it covers a total area of 606 km^2 along the Southwest shore of Lake Michigan and it hosts over 2.7 million people. Chicago Transit Authority (CTA) manages the municipal transportation system which includes heavy-rail system L, buses and commuter railway connecting the urban center with the surrounding suburbs. The Chicago Transit Authority (CTA) 'L' system diagram illustrates a hub-and-spoke rail network centered around the downtown Loop, featuring eight color-coded lines (Red, Blue, Brown, Green, Orange, Purple, Pink, and Yellow) that connect the central business district to the North, South, and West sides away from the lakeshore, with Lake Michigan forming the city and transit system boundary to the East, as well as providing direct service to O'Hare and Midway international airports [20]. The use of weekday movement and the business atmosphere in downtown makes Chicago significantly vulnerable to changes in the transit movement.

While the other case studies clearly show the longer-term effects of the COVID-19 pandemic, Figure 2 visually demonstrates the ridership dynamics in Chicago, the city most dependent on transportation in this study. Ridership increased and stayed relatively high, averaging between 2.8–3.1 million monthly passengers, from 2018 to 2019 in Panel A, because of the high demand for transit services before COVID-19, due to strong demand in dense employment centers, universities, and the large car-free population. In 2020, ridership dropped dramatically from nearly 2.8 million in February to about 0.7 million in April (a decline of more than 75%). In 2021, monthly figures for the recovery were still low, ranging from 1.1 to 1.8 million. Ridership continued to rise, though slowly, even after 2022 (which saw ridership increase to 1.6–1.9 million in peak months), suggesting a more modest, slower recovery. Panel B highlights the magnitude and extent of such transformation. The drop in 2019–2020 (grey dashed line) is steep, ranging from −65% to −76% between March 2020 and December 2020, with the largest decrease of about −76% in April 2020. The recovery during 2020–2021 (red dashed line) was positive and moderate, ranging from +50% to +69% in the summer and fall months. The changes for 2021–2022 (green line) remain positive but are quite small (+10% to +50%), indicating a steady recovery that did not reach 2019 levels by the end of 2022. The three phases of the dynamic model proposed in this study were well supported by these patterns, with the first phase, systemic shock in 2020, likely brought on by strict lockdowns, remote work mandates, and fears of crowded public places, followed by a plateau/partial adaptation in 2021 as hybrid work arrangements became more common and as employment in downtown areas stayed low.

The ridership shock experienced in Chicago lasted longer than in Houston and the average decline stood at 53.47% in 2020 [20]. The initial decline was due to the supply-side factors, including route closures, frequency of service, and shortages of personnel, as well as to the demand side, including the perception of risks and avoiding congested transit vehicles. Unlike Houston, where ridership had leveled off by mid-2021, Chicago had a slow recovery, which was conditioned by the concentrated employment patterns, a large reliance on public transit, and the relatively large share of car-free households. The CTA focused on basic services among low-income and frontline workers, which improved the consideration of social equity but at the cost of slower overall recovery. At the end of 2022, ridership started to recover, which can be explained by the implementation of the hybrid work model, reopening of schools, and reactivation of downtown. In spite of these improvements, the ridership remains below what it was before the pandemic, which suggests that there is change in mobility behavior structure. This fact is consistent with the literature stating that urban density and behavioral adaptation play a major role in transit resiliency. The experience in Chicago points out that transit-dependent systems have slower recovery and institutional inertia and risk perception by the population, which in turn entails the idea that adaptive policies, dynamic routing, multimodal integration, and demand forecasting are necessary to strengthen the resilience in the transport of the city.

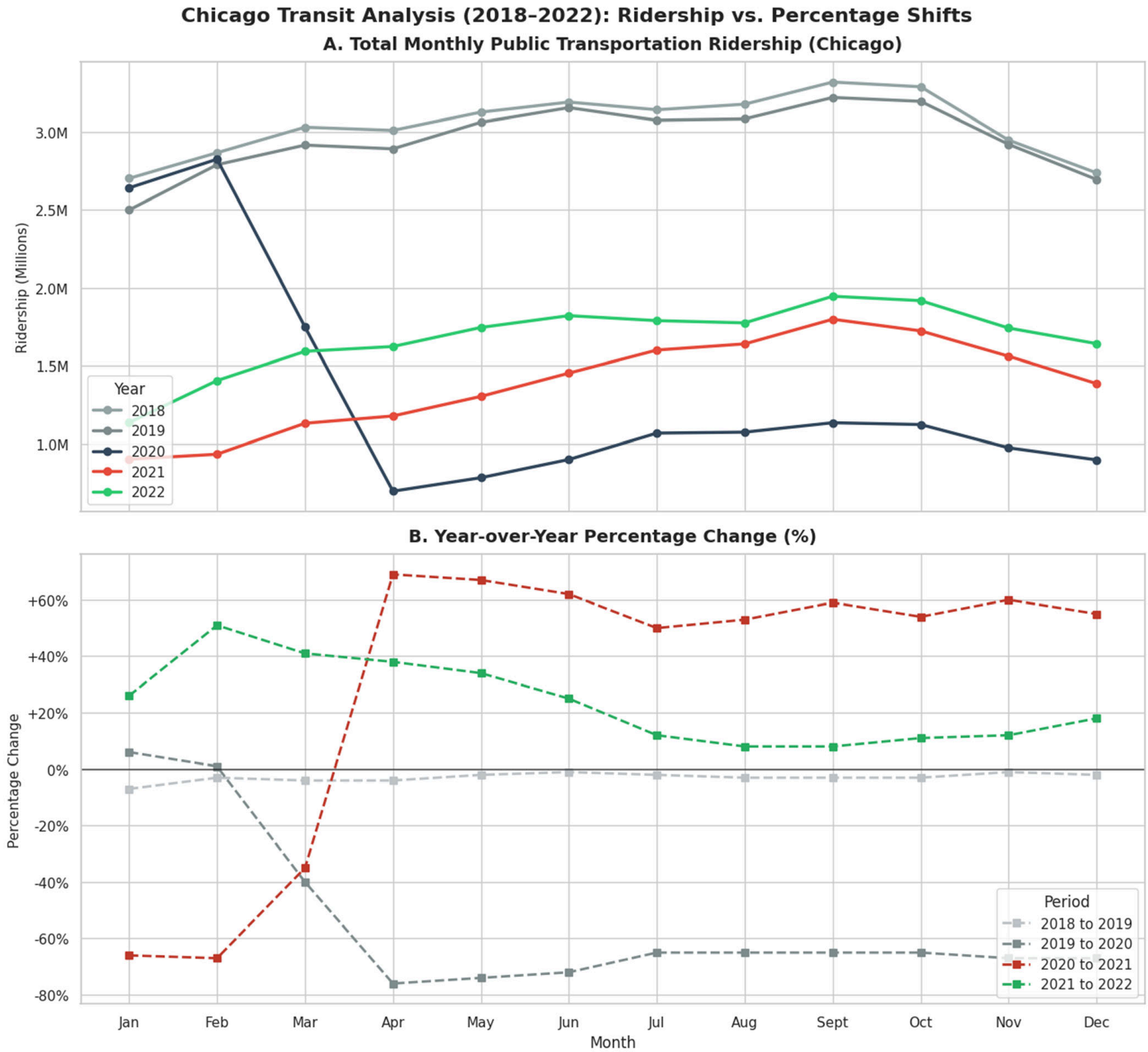

Figure 2. Comprehensive analysis of public transport ridership in Chicago, Illinois (2018–2022). (**A**) Total monthly ridership (in millions) showing trends across the five years. (**B**) Year-over-year percentage change in ridership, highlighting the severe shock in 2020 and gradual, incomplete recovery in 2021–2022.

4.3. Singapore

Singapore is a city-state found in the southeastern region of Asia that consists of one major island and 63 smaller islands. The city is one of the most populated urban areas in the world with a multicultural population, with an extremely integrated and technologically efficient transportation system [14]. The Singapore Mass Rapid Transit (MRT) and Light Rail Transit (LRT) system comprises an extensive island-wide network, including major rail corridors such as the North-South, East-West, North-East, Circle, Downtown, and Thomson-East Coast lines, complemented by localized LRT networks serving Bukit Panjang, Sengkang, and Punggol [21]. MRT/LRT network spans 240 km and consists of 160 stations with big interchanges such as Dhoby Ghaut, Orchard, and Paya Lebar, which serve over three million commuters daily.

Figure 3 clearly illustrates an example of Singapore's public transit ridership dynamics, and it exemplifies the resilience of a highly integrated, technologically advanced and centrally governed city-state. Ridership was also steady and strong in Panel A during the pre-pandemic years (2018–2019), ranging from around 1.1 to 1.25 million passengers per month. There is clear evidence of a sharp decline in 2020, with ridership falling to a low of approximately 0.2 million in May 2020 during the "Circuit Breaker" lockdown. Recovery began in late 2020 and gradually increased in 2021 to 0.6–0.9 million passengers per month. In 2022, ridership was almost back to pre-pandemic levels (1.05–1.1 million), reflecting one of the more successful recovery experiences among the cities studied. The intensity and timing of changes are indicated in Panel B. The 2019–2020 period (grey dashed line) indicates significant decreases, the largest of which were around −70% to −80% in April-May 2020. The recovery phase in 2020–2021 (red dashed line) was strong with rates higher than +200% in the peak months of April and May 2021. The 2021–2022 period (green dashed line) shows positive, but less dramatic growth, generally between +30% and +80% which reflects near-term stabilization to a "new normal" around pre-pandemic volumes. The three-phase dynamic model proposed in this study (systemic shock in 2020 due to strict movement restrictions and health measures; plateau/partial adaptation in late 2020–early 2021 with regulated operations and behavioral adaptation; and heterogeneous recovery in 2021–2022, which was systematic and effective in Singapore) is well supported by the patterns observed in Figure 3.

4.4. Dubai (United Arab Emirates)

With a population of around 2,459,068 (estimated), Dubai is located in the southeastern Arabian Gulf, and it occupies an area of 4114 km^2. The municipal transportation system is one of the most integrated systems in the Middle East, including buses, the Metro (light rail), trams, taxis, and water taxis. The Dubai Metro service features two main corridors: The Red Line, which travels linearly along the primary coastal highway connecting major hubs from Jebel Ali in the southwest to areas near the Dubai International Airport in the northeast, and the Green Line, which loops through the older central districts around Dubai Creek; both lines intersect at the Union and BurJuman transfer stations [22]. The bus network consists of 1518 vehicles that cover 119 routes, which are linked to 35 Metro lines, 12 intercity lines, 62 local lines, and eight express lines; the network covers 82% of the city area and carries about 3692 passengers per week. The Dubai Metro consists of the Red Line (Centrepoint–Expo 2020), with seven main stations, and the Green Line, which serves both commuter and tourist locations, as well as some of the older neighborhoods. The Dubai Tram, which was commissioned in November 2014, connects 11 stations and it is connected to the Metro system [19].

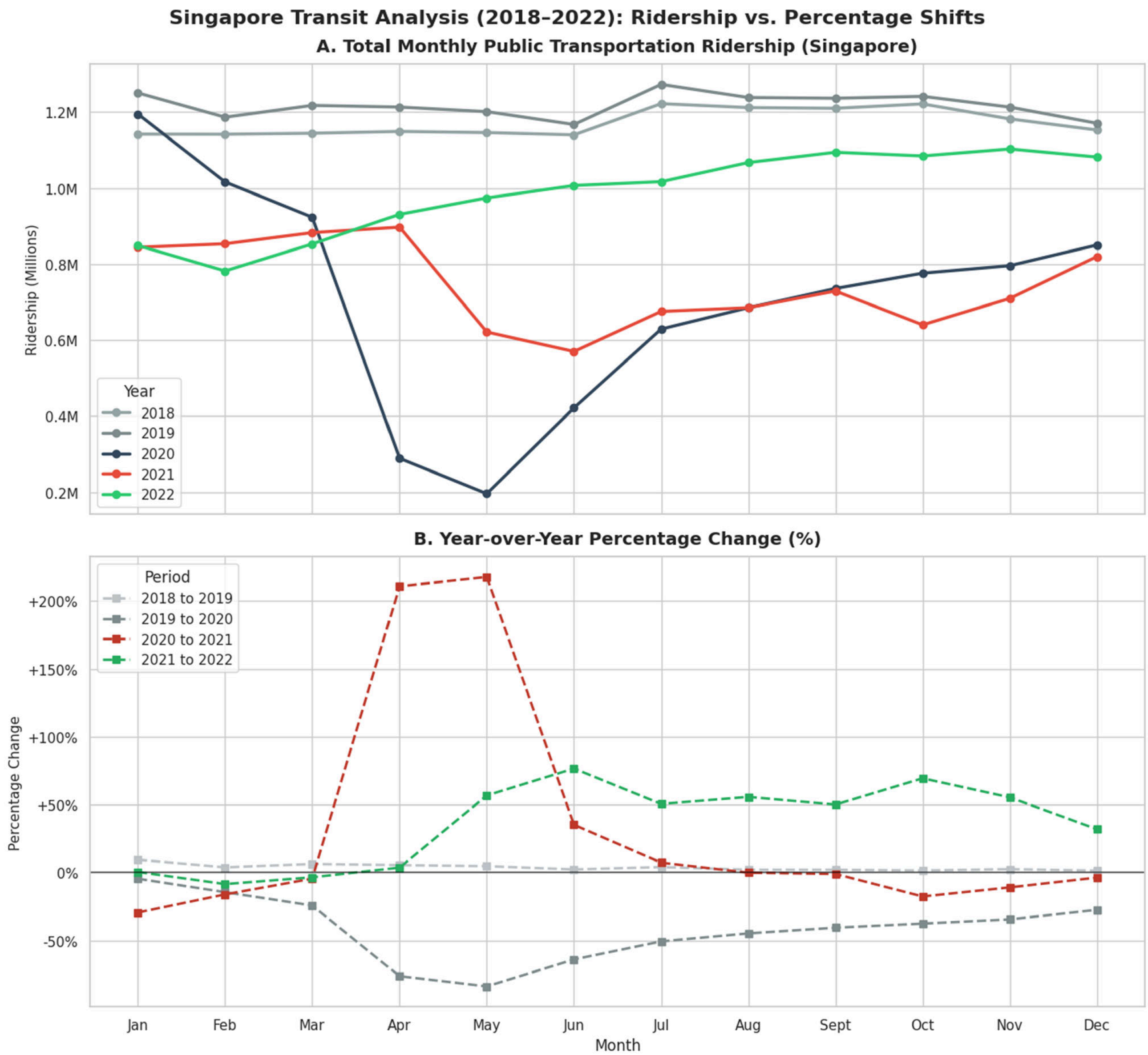

Figure 3. Comprehensive analysis of public transport ridership in Singapore (2018–2022). (**A**) Total monthly ridership (in millions) showing trends across the five years. (**B**) Year-over-year percentage change in ridership, highlighting the sharp 2020 decline and strong, steady recovery in 2021–2022.

The COVID-19 pandemic led to a significant loss of ridership. Figure 4 shows how drastically the COVID-19 pandemic affected Dubai's public transit system, and how quickly Dubai recovered, given its high degree of centralization and technological advancement. Prior to the pandemic, ridership continued to rise, and in Panel A, monthly passenger numbers reached 15–18 million or more each month in many cases. There was a significant drop in 2020 as ridership dropped to very low levels (e.g., below 1 million in March–April). In 2021, recovery started and has been clearly on the upward trend, and by 2022, ridership had not only exceeded pre-pandemic levels but also reached record highs, reaching close to 29–30 million passengers in several months. This V-shaped/upside-down V-shaped recovery curve illustrates Dubai's capacity to bounce back and even surpass its previous demand when the restrictions were lifted. Both the decline and the rebound are shown as being intense in Panel B (on a log scale to accommodate the extreme values). The 2019–2020 period exhibits significant declines, ranging from −95% to −97%, during the peak lockdown months (April and November). The recovery was spectacular (red dashed line) in 2020–2021, with growth of over +4000% in November 2021, and remaining above +100% throughout the year. Growth for 2021–2022 (green line) remains positive but more moderate and is now at a higher level. The visual patterns in Figure 4 strongly confirm the three-phase model of systemic shock (in Dubai in 2020 due to strict lockdowns and suspension of services), plateau/partial adaptation (late 2020–early 2021), and heterogeneous recovery (2021–2022), where recovery was exceptionally intense and even surpassed pre-pandemic levels in Dubai. Centralized governance, through the RTA, proactive infrastructure expansions (such as the Red Line extensions), advanced technology (contactless ticketing, AI crowd management), and the return of international tourism and Expo 2020 were all responsible for this swift recovery.

Figure 4. Comprehensive analysis of public transport ridership in Dubai, United Arab Emirates (2018–2022). (**A**) Total monthly ridership (in millions) showing trends across the five years. (**B**) Year-over-year percentage change in ridership (log scale applied due to extreme recovery peaks), highlighting the sharp 2020 decline and exceptionally strong rebound in 2021–2022.

4.5. Calgary (Canada)

Calgary, the major metropolitan center in Alberta, Canada, is an economic hub for the energy industry. The Calgary Transit network includes the CTrain light rail system, featuring the Red Line (operating between Tuscany in the northwest and Somerset-Bridlewood in the south) and the Blue Line (operating between Saddletowne in the northeast and 69 Street SW in the west), which share a central downtown transit corridor and integrate with various cross-town Bus Rapid Transit (BRT) routes [23]. The city's public transportation system is operated by Calgary Transit, which forms its public transportation system and includes the CTrain Light Rail Transit (LRT) system, supplemented by bus and park-and-ride services that offer multimodal travel throughout the urban center.

The COVID-19 pandemic created a strong demand effect on transit. The ridership trends in Calgary are well summarized in Figure 5 and illustrate the fragility of a medium-sized North American city dependent on cars. Ridership numbers were stable and relatively high during the pre-pandemic years (2018–2019) and were typically between 12 and 14 million passengers each month, with commuters coming into the city to work in downtown energy jobs and to take advantage of the CTrain light rail network. There was a sharp drop in 2020, with ridership plummeting from more than 13 million in early 2020 to approximately 2 million in April/May. Recovery continued to be anemic in 2021, even when compared to pre-pandemic numbers. The ridership rebound was slow and incomplete. In 2022, ridership saw some improvement (especially during the fall months) but remained significantly lower than the 2018–2019 baseline. Changes are illustrated by the size of the points in Panel B. The 2019–2020 data (grey dashed line) indicate relatively small pre-pandemic variations in numbers and large decreases of around −80% to −85% in April and May 2020. The recovery (red dashed line) was slow in 2020–2021, with positive trends beginning in mid-2021, but the recovery was not complete, ranging between −65% and −45% in later months relative to 2020. Partial recovery is shown in the 2021–2022 period (green dashed line), with spring growth showing considerable improvement (+107% in April) and more modest improvements later in the year.

The patterns in Calgary are very similar to the three-phase dynamic model found across the six cities, including a systemic shock in 2020 (as a result of lockdowns, remote work adoption, and diminished commuting), a plateau/partial adaptation in 2021 (slow recovery, hybrid working, and diverse recovery), and incomplete recovery in 2022 (high car dependency, low-density urban form, and energy-sector working patterns that enabled remote working). In comparison to centralized, dense cities, such as Dubai or Singapore, Calgary requires adaptive solutions over the long term to build transit resilience, which demonstrates how urban form, employment distribution, and cultural considerations affect mobility recovery.

4.6. Cairo (Egypt)

The largest urban transit system on the African continent is located in Cairo, the capital city of Egypt and the light rail and metro streets are the heart of the city. The Cairo Metro, owned by the state, connects the residential, commercial, and industrial sectors of the city with the suburbs, serving millions of daily commuters. The impact of the COVID-19 outbreak on transit ridership in Cairo provides an understanding of the resilience of the public transportation system in the developing-city setting [18]. Ridership drops in Cairo were more complex than in cities like Dubai and Singapore, as they were due to limited teleworking potential, low public transit fares, and heavy dependence on the metro by low-income commuters. The Cairo Metro network consists of three main transit lines serving the Greater Cairo area: Line 1 connecting Helwan in the south to New Marg in the northeast, Line 2 running from Shubra Al Khaimah in the north to El Monib in the southwest, and Line 3 extending from Adly Mansour in the east to cross-Nile destinations in the west like the Rod El Farag Corridor and Cairo University, with central interchange stations located at Sadat, Al-Shohadaa, and Attaba [24].

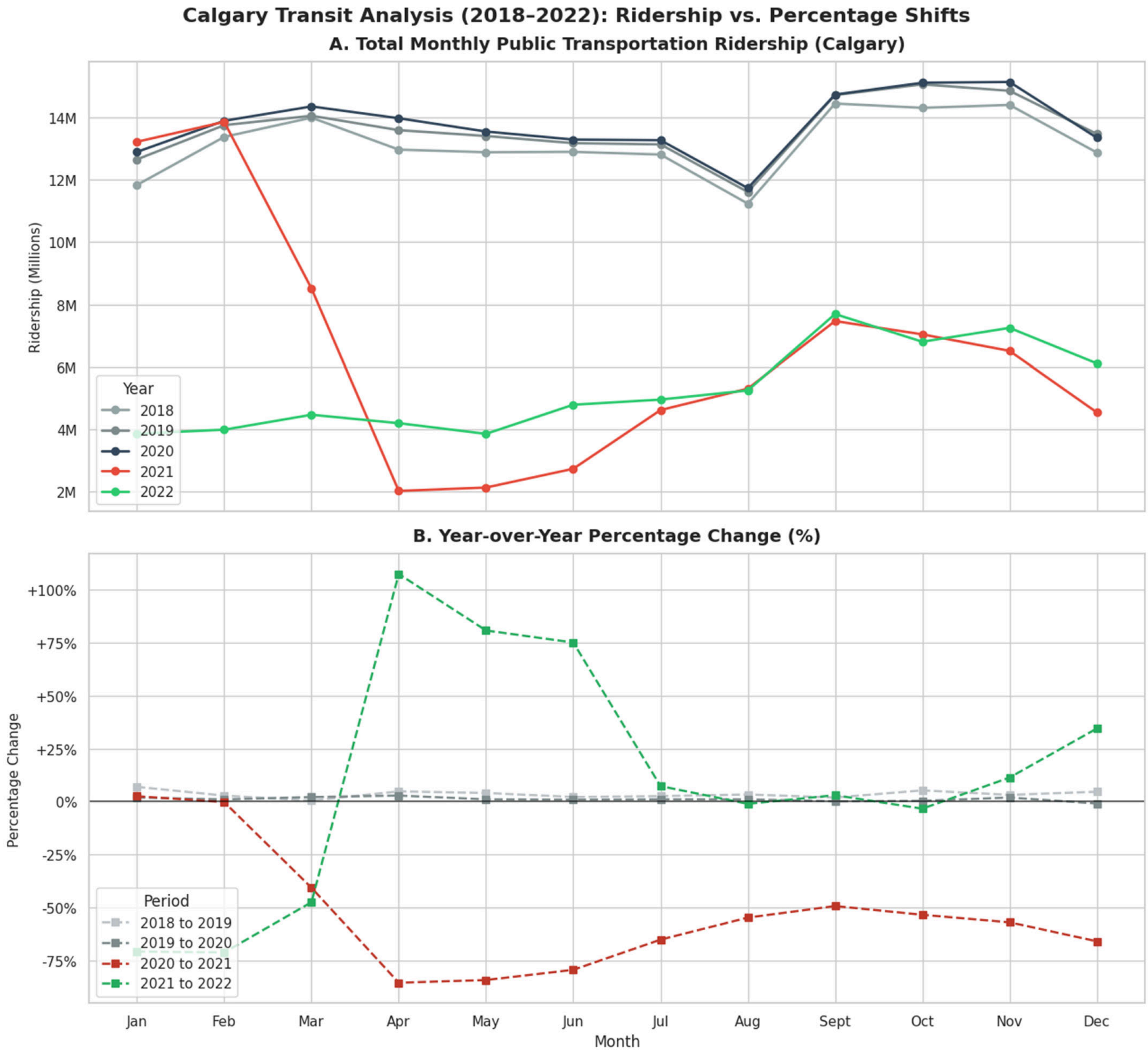

Figure 5. Comprehensive analysis of public transport ridership in Calgary, Canada (2018–2022). (**A**) Total monthly ridership (in millions) showing trends across the five years. (**B**) Year-over-year percentage change in ridership, highlighting the severe shock in 2020 and partial recovery in 2021–2022.

The three-phase dynamic pattern in Cairo's public transit system is clearly depicted in Figure 6, before the COVID-19 pandemic and following its impact. Panel A shows monthly ridership, and Panel B shows the percentage change each month compared to the previous year, providing more detail on the scale and duration of disruption and recovery. Ridership in Panel A was relatively stable from 2018 to 2019, with a ridership level of around 25–30 million passengers per month, indicating a consistent demand for public transportation before the pandemic, due to Cairo's high poverty levels and lack of competition from private transportation. There was a sharp drop in 2020, with ridership as low as ~5 million in March–April 2020, reflecting the immediate systemic shock during the lockdowns. The recovery started in late 2020, picked up pace in 2021, and is now growing monthly toward pre-pandemic levels. Ridership levels by 2022 were not only restored but exceeded those of previous years, with ridership peaking in several months at around 40 million passengers. As the curve suggests, Cairo's recovery has been in a V-shape, with a strong emphasis on necessity instead of policy or technological solutions.

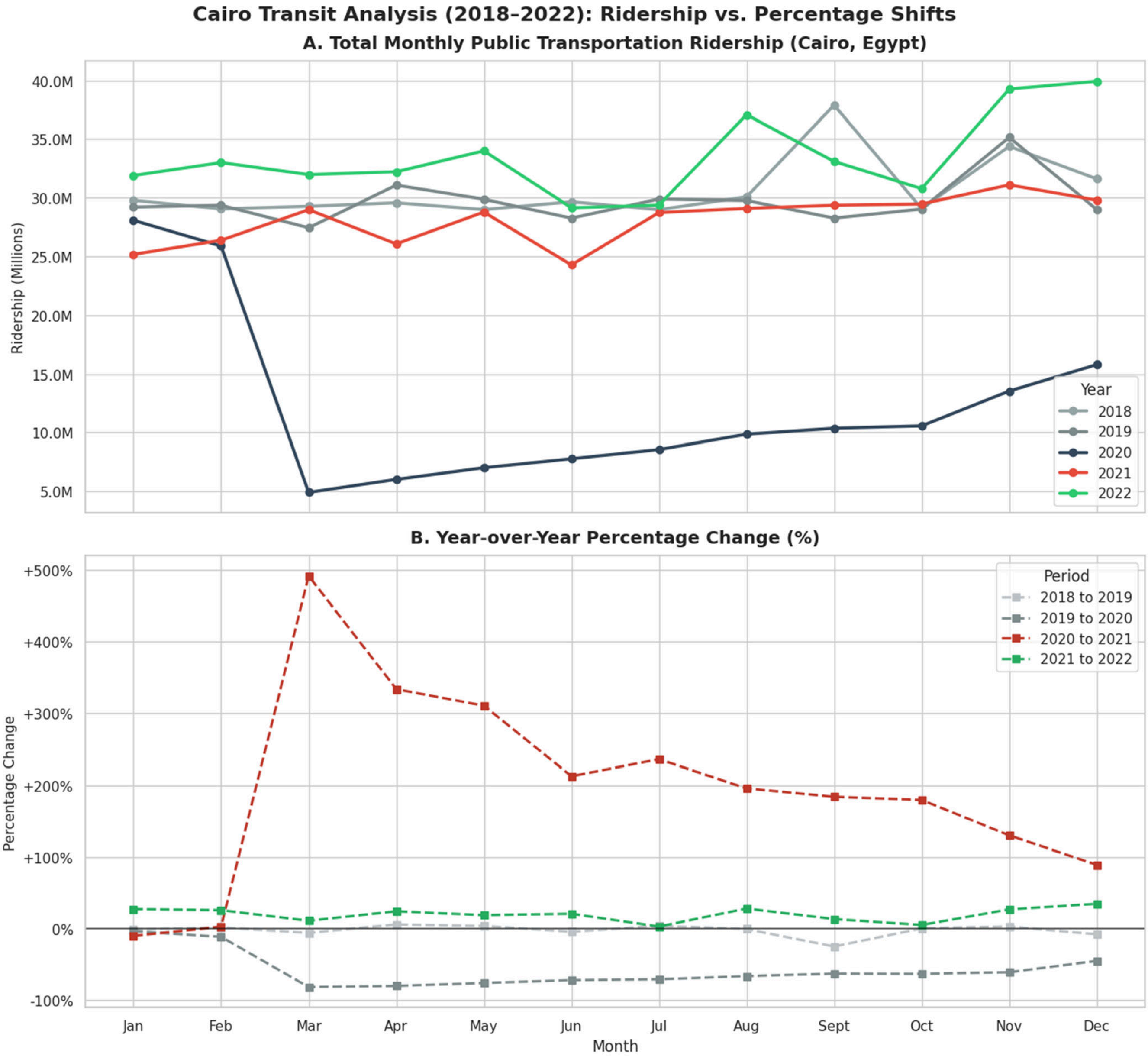

Figure 6. Comprehensive analysis of public transport ridership in Cairo, Egypt (2018–2022). (**A**) Total monthly ridership (in millions) showing trends across the five years. (**B**) Year-over-year percentage change in ridership, highlighting the dramatic shock in 2020 and strong recovery in 2021–2022.

These changes are even more starkly evident in Panel B. The 2019–2020 period (grey dashed line) reveals a steady decline of −60% to −80% between March and June 2020—the months of peak lockdown—with the steepest decline of almost −82% in March. The recovery (red dashed line) was very robust in 2020–2021, with growth above +490% in March 2021 and above +180% for most of the year. The 2021–2022 time window (green line) shows signs of stabilization with moderate positive growth (0–50%), suggesting a new normal with slightly higher levels than before the pandemic.

Patterns of systemic shock in 2020, plateau/adaptation in 2021, and heterogeneous recovery in 2022 are consistent with the overall three-phase framework that was identified across the six cities. The recovery was, however, unique in Cairo: in cities with a focus on private vehicle use, like Calgary or Chicago, for example, behavioral changes in the way people travel contributed to the continued low ridership, whereas the situation was different in Cairo, where the socioeconomic necessity of the service led to a swift recovery. There were limited options for low-income commuters, and the metro affordability helped keep demand going even during periods of health risk. This resilience, however, also suggests vulnerabilities because, in the event of recovery periods, peaks of congestion occur, which further impact public health outcomes, as emphasized in the epidemiology context of this Special Issue.

4.7. Cross-Case Comparative Analysis and Synthesis

Table 1 used the standard p-value threshold of 0.05 ($\alpha = 0.05$) to calculate the statistical significance. A p-value of less than 0.05 shows that the difference in annual mean ridership is statistically significant and is unlikely to have occurred by chance; thus, the variations are within the normal ranges of fluctuation [2,25]. In this respect, the t-value is the ratio of the difference between means to sample variability; the larger the value of the t-value in absolute terms, the smaller the p-value, and the more significant is the evidence of a real change in ridership [14].

Table 1. Comparative statistical analysis of railway transit ridership trends across case study cities over the period 2018–2022.

Urban Area/City	2018–2019	2019–2020	2020–2021	2021–2022
Houston	0.065	<0.001 *	0.230	<0.001 *
Chicago	0.243	<0.001 *	0.530	0.015 *
Singapore	0.003 *	<0.001 *	0.075	<0.001 *
Dubai	0.014 *	<0.001 *	0.235	<0.001 *
Calgary	0.711	<0.001 *	0.313	<0.001 *
Cairo	0.315	<0.001 *	<0.001 *	<0.001 *

Note: Values are p-values from paired t-tests. (*) indicates statistical significance at $p < 0.05$.

The explanation of the speed of disruption and recovery is through the interpretation of t-values and significance on a year-by-year basis. In 2019–2020, the first COVID-19 lockdowns are associated with significant t-values in nearly all cities, and they demonstrate a large drop in ridership, similar to reports in Sweden and Australia [2,5]. The following insignificance in 2020–2021 is a sign of stabilization period of behavioral adjustments, working remotely, and still with caution [12]. Renewed significance in 2021–2022 refers to a recovery phase in line with the development of vaccination and renewed trust in free movement [16,19].

Table 1 summarizes a relative statistical review on the inter-annual changes of the ridership of railway transit in six metropolitan areas, thereby offering a statistical model of assessing the scale and speed of disruptions and recoveries during the pandemic. The trends of the observed significance reflect three common stages typical of any urban system, namely, a global shock in 2019–2020, a plateau in 2020–2021, and a lopsided recovery in 2021–2022. The acute significance of the first quarter is consistent with the appearance of the COVID-19 pandemic, which introduced the world to the previously unseen mobility restrictions [13]. This fast impact is comparable to previous results in Sweden and Australia, where ticket validations and the number of passengers decreased markedly because of lockdowns and travel phobia [2,4].

The comparatively insignificant 2020–2021 signifies a stabilization phase of a risk-averse behavioral adjustment and remote work regardless of the relaxation rules [20]. The reemergence of importance in 2021–2022 point to nascent recovery, which is caused by the policy relaxation, an increase in the rate of vaccination, and growing confidence among the population [16,19]. Though these time patterns are common, the magnitude and direction of statistical change differ among the six cities as an example that governance structure, economic resilience, and technological preparedness determine the adaptability of the systems. There were better rebounds in such cities as Singapore, Dubai, and Houston, where the institutional flexibility and digital infrastructure are more characteristic. Centralized, data-driven management allowed Singapore to make real-time changes to its service levels and incorporate digital monitoring and stabilize transit operations by 2021 [25]. Likewise, Dubai which has a technologically advanced network and an economy that depends on tourism was able to recover faster as soon as international travel was started once again [16]. In the case of Houston, the adaptive resilience was manifested in the decentralized management and the ability to schedule flexibly with the help of digital integration METRO.

On the other hand, Chicago and Calgary were also characterized by slower recovery, and the non-significant changes were observed in 2020–2021, and only recovered its significance in 2021–2022. Both cities rely on commuting and face-to-face jobs; therefore, the hybrid work adoption prolonged their status of stagnation in the number of riders [4,19]. Cairo, in turn, demonstrated stable ridership importance throughout the majority of years, which is not a sign of policy adaptation, but the necessity of such resilience due to socioeconomic reliance on cheap transit as opposed to the institutional innovation [7]. These findings prove that statistical significance per se is a measure of various kinds of resilience: policy-based in Houston, Singapore, and Dubai; structural and economic in Chicago and Calgary, and socially forced in Cairo. Instead, resilience is a multidimensional phenomenon that is dependent on governance agility, social structure, and economic necessity.

These patterns methodologically justify year-to-year significance testing as more sensitive to reflect the dynamics of the system, as compared to baseline comparisons, since it can reveal non-linear oscillations, instead of straightforward trends [15]. In addition, the *t*-tests are to be framed with the governance and behavioral indicators as univariate significance as such can be deceiving in the strength of recovery [5,13]. Remote work compliance and ongoing traveling restrictions are in line with the plateau of 2020–2021 [26]. The recovery also was moderated by fiscal support systems all provided with the interim funding and continuity of services recovered faster and more financially constrained ones lost ground (Calgary, Cairo) were lagged behind [14,19].

Overall, this cross-case analysis has verified that resilience of the public transportation during COVID-19 was in the three-step path of collapse, stabilizing and adaptive recovery. The recovery was also dependent on the level of governance and socioeconomic status: in the cities with high income and a high level of digital development, the recovery process was adjusted, whereas in the low-income environment, the maintenance of the services was performed not due to the innovations but because of the necessity. These results contribute to the general assumption that the technological preparedness, financial stability, and socially responsible governance of urban transportation is the key to sustainable resilience [16,19]. Theoretically, Table 1 shows that the restoration of public transportation systems is path-dependent and context-specific, representing a negotiated compromise among institutional flexibility, behavioral adjustment, and socioeconomic persistence.

5. Conclusions

This is a comparative study of urban transportation ridership in six cities: Houston, Chicago, Singapore, Dubai, Calgary and Cairo and their subsequent recovery paths. The COVID-19 pandemic was a global shock, but local governance, socioeconomic reliance on public transportation, technological integration, and urban space played a mediating role in shaping the pandemic's impact on transit systems. The results point to three-phase dynamics: a phase of systemic shock in 2020, followed by a partial adaptation phase in 2021, and a diverse recovery phase in 2022. Recovery trends varied across the cities. Dubai and Cairo both recovered quickly, in a V-shaped pattern, due to the role of tourism and the continued movement of essential workers, and due to the centralized governance. The situation was quite different in Chicago and Calgary, however, where governance structures were more decentralized, private car ownership was greater and remote working practices were still common. The gradual and policy-driven recovery in Singapore highlights the need for integrated, multimodal management and digital interventions to rebuild trust in public transportation. Houston had a comparatively quick normalization, perhaps due to the flexibility of regulations and less need for public transport. These intercity variations show that the capacity of the infrastructure is just one of the factors that contribute to making a transportation system resilient; that resilience is in fact a system phenomenon, and that it depends on the interaction among governance adaptability, technological facilitation, behavioral responses, and socio-spatial urban dynamics. The results also indicate a rethinking of the concept of transit resilience. Resilience is not only about the speed of recovery but also about the capacity of institutions or groups of institutions to learn, adapt to systemic shock, and change their behavior. Low-density, car-dependent cities could be better served by focusing on adaptive, multimodal cities and increasing equitable service accessibility. In turn, transit-dependent cities need to incorporate health security provisions, automation, and flexible service design into long-term planning systems to ensure that users continue to trust the system and that it remains operational. The empirical results show that changes in ridership during the initial shock and recovery phases were statistically significant, whereas changes during the intermediate plateau phase were generally not statistically significant. All cities had an overall trend of three phases but the amount and duration of the change differed with some cities deviating from the overall trend; Cairo was notable for the amount of change as it continued to have a significant variation in the plateau phase. Initial findings also indicate that the differences in ridership change are more related to how governance is structured and their dependence on cars, rather than population size or urban area itself. There are several drawbacks that should be noted. The analysis relies on aggregate ridership data, without accounting for differences in transportation modes or origin–destination flows, which limits the ability to draw conclusions about intra-urban mobility patterns. Findings are limited in generalizability because the sample size is limited to six cities, in part due to unavailable data. Furthermore, epidemiological data were also not used statistically in the form of formal models but rather qualitatively, which constrained the scope of establishing causal relationships between disease dynamics and mobility patterns. There is also the limitation of a small number of observations in the correlation analysis, which limits the statistical power. Future research should include more locations, disaggregate mobility data, and use more sophisticated statistical models, such as panel and mixed-effects regression, to better explore the relationship between epidemiological variables and transit use.

The results highlight the need for strategies that are grounded in context from a policy perspective. In low-density cities in which driving has become the primary mode of transportation, transit agencies need to focus on flexible, demand-responsive services and encourage the use of hybrid travel. In highly centralized and technologically advanced systems, continued investment in real-time monitoring and contactless technologies can help to increase system resilience and user trust. Policy should concentrate on enhancing public health protections in transit settings, such as improved air exchange, crowd control, and emergency communication systems, in cities where transit use is motivated by necessity. In all circumstances, contingency operational planning, multi-source funding and collaboration between the transit and public health sectors will be key to getting ready for future high-impact events. In sum, post-pandemic urban transit systems are changing, not reverting to old models but moving toward a more resilient, adaptive, and trust-based model of urban transportation.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are restricted due to participant privacy and institutional policy but are available from the corresponding author upon reasonable request.

Acknowledgments: The author expresses gratitude to all contributors and collaborators who supported this research effort.

Conflicts of Interest: The author declares no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial Intelligence
CAPMAS	Central Agency of Public Mobilization and Statistics (Egypt)
CTA	Chicago Transit Authority
LRT	Light Rail Transit
METRO	Metropolitan Transit Authority of Harris County (Houston)
MRT	Mass Rapid Transit (Singapore)
RTA	Roads and Transport Authority (Dubai)
SBS	SBS Transit (Singapore)

References

1. Ritchie, H.; Roser, M. The World Population Is Changing: For the First Time There Are More People over 64 than Children Younger than 5. Our World in Data. 2023. Available online: https://ourworldindata.org/world-population-age (accessed on 10 November 2025).
2. Manfreda, A.; Erjavec, J. Nudging towards sustainable public transportation. In *Handbook of Research on Promoting Sustainable Public Transportation Strategies in Urban Environments*; IGI Global: Hershey, PA, USA, 2023; pp. 120–140.
3. UITP. National Public Transport Statistics. UITP Statistic Brief. Available online: https://www.uitp.org/statistics (accessed on 10 November 2025).
4. Hensher, D.A.; Wei, E.; Beck, M.J.; Balbontin, C. The impact of COVID-19 on cost outlays for car and public transport commuting—The case of the Greater Sydney Metropolitan Area after three months of restrictions. *Transp. Policy* **2021**, *101*, 71–80. [CrossRef]
5. Mack, E.A.; Agrawal, S.; Wang, S. The impacts of the COVID-19 pandemic on transportation employment: A comparative analysis. *Transp. Res. Interdiscip. Perspect.* **2021**, *12*, 100470. [CrossRef] [PubMed]
6. Tirachini, A.; Cats, O. COVID-19 and public transportation: Current assessment, prospects, and research needs. *J. Public Transp.* **2020**, *22*, 1–21. [CrossRef]
7. Luo, K.; Lei, Z.; Hai, Z.; Xiao, S.; Rui, J.; Yang, H.; Jing, X.; Wang, H.; Xie, Z.; Luo, P.; et al. Transmission of SARS-CoV-2 in public transportation vehicles: A case study in Hunan Province, China. *Open Forum Infect. Dis.* **2020**, *7*, ofaa430. [CrossRef] [PubMed]
8. Liu, Y.; Huang, Z.; Luo, X.; Ma, H.; Li, Z. Insights of airborne transmission within urban rail transit carriage environments after the COVID-19 pandemic. *Indoor Built Environ.* **2026**, *online first*. [CrossRef]
9. Dong, E.; Du, H.; Gardner, L. An interactive web-based dashboard to track COVID-19 in real time. *Lancet Infect. Dis.* **2020**, *20*, 533–534. [CrossRef] [PubMed]
10. World Health Organization. WHO Coronavirus (COVID-19) Dashboard. Available online: https://covid19.who.int/ (accessed on 10 June 2026).
11. Munawar, H.S.; Khan, S.I.; Qadir, Z.; Kouzani, A.Z.; Mahmud, M.A.P. Insight into the impact of COVID-19 on Australian transportation sector: An economic and community-based perspective. *Sustainability* **2021**, *13*, 1276. [CrossRef]

12. Mogaji, E.; Adekunle, I.; Aririguzoh, S.; Oginni, A. Dealing with impact of COVID-19 on transportation in a developing country: Insights and policy recommendations. *Transp. Policy* **2022**, *116*, 304–314. [CrossRef]
13. Huang, J.; Wang, H.; Fan, M.; Zhuo, A.; Sun, Y.; Li, Y. Understanding the impact of the COVID-19 pandemic on transportation-related behaviors with human mobility data. In Proceedings of the 26th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining, New York, NY, USA, 6–10 July 2020; pp. 3443–3450.
14. Xiao, J. Funding resiliency during the pandemic: Transit operational funding and the impacts of COVID-19. *Preprint* **2021**.
15. Gkiotsalitis, K.; Cats, O. Public transport planning adaption under the COVID-19 pandemic crisis: Literature review of research needs and directions. *Transp. Rev.* **2021**, *41*, 374–392.
16. Tarasi, D.; Daras, T.; Tournaki, S.; Tsoutsos, T. Transportation in the Mediterranean during the COVID-19 pandemic era. *Glob. Transit.* **2021**, *3*, 55–71. [CrossRef] [PubMed]
17. CAPMAS. Central Agency for Public Mobilization and Statistics, Egypt. Available online: http://www.capmas.gov.eg (accessed on 10 November 2025).
18. Jenelius, E.; Cebecauer, M. Impacts of COVID-19 on public transport ridership in Sweden: Analysis of ticket validations, sales and passenger counts. *Transp. Res. Interdiscip. Perspect.* **2020**, *8*, 100242. [CrossRef] [PubMed]
19. Houston METRORail System Map. Available online: https://www.houstontx.gov/abouthouston/lightrail/fullmap-large.pdf (accessed on 10 June 2026).
20. Chicago Transit Authority 'L' System Diagram. Available online: https://www.transitchicago.com/assets/1/6/ctamap_Lsystem.pdf (accessed on 10 June 2026).
21. Singapore MRT and LRT System Map. Available online: https://www.lta.gov.sg/content/ltagov/en/getting_around/public_transport/rail_network.html (accessed on 10 June 2026).
22. Dubai Metro Network Guide. Available online: https://www.luxhabitat.ae/the-journal/dubai-metro-guide/ (accessed on 10 June 2026).
23. Calgary Transit Complete Map. Available online: https://dailyhive.com/calgary/calgary-transit-complete-map-2018 (accessed on 10 June 2026).
24. Cairo Metro Network Map. Available online: https://cairometro.gov.eg/en/Maps (accessed on 10 June 2026).
25. Yu, W.; Tedds, L.M.; Petit, G. *Assessing Trends and Patterns of the Effect of COVID-19 on Public Transit Revenues in the City of Calgary*; MPRA Paper No. 115350; Munich Personal RePEc Archive: Munich, Germany, 2022.
26. Pedersen, M.J.; Favero, N. Social distancing during the COVID-19 pandemic: Who are the present and future noncompliers? *Public Adm. Rev.* **2020**, *80*, 805–814. [CrossRef] [PubMed]

https://doi.org/10.3390/covid6070130