# Post-COVID Travel Patterns: Evidence Base for OD, Trip Purpose, and Time-of-Day Shifts and Implications for ABM Recalibration

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# Executive Summary

## Summary of Key Findings

Remote and Hybrid Work as the Dominant Structural Shift

Remote work surged during the pandemic and remains 2 - 3× above 2019 levels. Fewer commuters and flatter AM/PM peaks persist nationally and in California, with hybrid schedules continuing to suppress peak congestion even as total Vehicle Miles Traveled (VMT) returns to or exceeds pre-COVID levels.

VMT Recovery but Persistent Peak Spreading

National and California VMT have fully rebounded (around 1 - 2% above 2019), yet congestion remains substantially lower because of peak spreading, altered commute timing, reduced travel by telework-compatible industries, and broader midday travel.

Major Shifts in Trip Purpose, Frequency, and Length

2022 National Household Travel Survey (NHTS) data show fewer daily person trips but longer average trip lengths. Shopping/personal-errands travel dropped, driven by e-commerce and delivery growth. Midday and early PM travel increased, influenced by hybrid work schedules and school patterns. These changes affect tour formation, trip generation, and trip length distributions, posing recalibration needs for activity-based models (ABMs).

Fundamental Changes in Time-of-Day Profiles

Evidence from multimodal datasets reveals bifurcated AM peak, earlier and broader PM peak, shifting from 5 p.m. to around 3 p.m. in many regions, and midday dominance, with nearly half of trips occurring between 9 a.m. - 4 p.m. These patterns undermine pre-2019 time-of-day model structures.

Transit Ridership Partial and Uneven Recovery

Transit has recovered only 60 - 75% of pre-COVID ridership despite recovered roadway VMT. Rail suffered deeper losses than bus, and major metros face industrial-scale fare revenue declines and workforce shortages. Structural ridership changes driven by telework and safety perceptions need to be embedded in modeling frameworks.

Inequities in Travel Recovery and Remote Work Access

Remote-work feasibility varies sharply by income, occupation, education, and race. Low-income and essential workers continue pre-COVID commute patterns and face reduced transit reliability and accessibility, higher auto cost burdens, and limited access to remote-eligible work. These disparities contradict many models' use of uniform telework assumptions.

Built-Environment Effects Persist

Compact, walkable, transit-supportive environments continue to reduce trip lengths and support local travel. Conversely, job-dense downtowns remain suppressed, and suburban/family-oriented areas show stronger VMT rebound. These distributional shifts require updated destination choice, accessibility, and mode choice calibration.

Travel Demand Models Are Not Well Aligned with Post-COVID Evidence

Only around 10 - 37% of California Metropolitan Planning Organizations (MPOs) have implemented post-COVID adjustments. Most continue to rely on 2014 - 2019 base years, with outdated commute intensities, transit use, tour patterns, and time-of-day curves. This poses risks for Sustainable Communities Strategy (SCS) evaluations, VMT impact analysis, project-level forecasting, and induced-travel estimation.

Emerging Modeling Approaches Offer Solutions

Recent innovations (e.g., latent-class telework models, integration of in-home activities, machine-learning-enhanced activity-chain estimation, and multi-day needs-based frameworks) provide clear pathways for modernizing ABMs to reflect flexible post-COVID behavior.

## Identified Gaps

Data and Measurement Gaps

- Limited post-2022 data; hard to separate recovery from lasting change.
- No continuous, comparable California travel survey.
- Weak measurement of non-work trip shifts and delivery/e-commerce impacts.
- Inconsistent Work From Hom (WFH)/telework definitions across datasets.

Behavioral Uncertainties

- Long-term hybrid work patterns are still unclear.
- Limited evidence linking relocation to VMT changes.
- Conflicting findings on non-work travel rebound and trip-chaining shifts.

Modeling Gaps

- Most models still rely on pre-COVID behavior.
- Telework is poorly represented as a behavioral choice.
- Insufficient modeling of induced VMT, freight/delivery, and time-of-day shifts.

Equity Gaps

- Telework capability is not sufficiently segmented by income, race, occupation.
- Insufficient statewide data on travel challenges faced by low-income households.
- Limited understanding of how service cuts, safety issues, and off-peak patterns affect transit-dependent riders.

Policy & Application Gaps

- Post-COVID behavior may misalign with Senate Bill (SB) 375/SCS assumptions.
- Limited VMT sensitivity testing and weak integration of employer policies under new behavioral patterns.
- Observed trends are not consistently translated into model parameters.

## Recommended Next Steps

Strengthen the Post-COVID Evidence Base

- Conduct new California-specific data collection capturing non-work purposes, trip chaining, delivery patterns, and telework permanence.
- Expand empirical datasets on equity impacts, particularly for transit-dependent and low-income populations.

Update and Recalibrate Modeling Frameworks

- Replace pre-COVID assumptions with updated commute patterns, telework rates, non-work trip generation, and new peak-period dynamics.
- Model telework as an explicit choice and incorporate industry capability, household factors, hybrid frequency, and day-specific patterns.
- Enhance ABM capabilities and add dynamic time-of-day scheduling, stronger in-home activity modeling, and multi-day activity patterns.
- Update modules to reflect persistent e-commerce growth.

Advance Future Research

- Evaluate residential relocation trends and their long-term VMT and mode-choice implications.
- Quantify hybrid workers' discretionary travel behavior.
- Investigate new transit service design under sustained hybrid commute patterns.

# Detailed Findings

This literature review synthesizes post-COVID evidence on changes in origin-destination (OD) patterns, trip purposes, and time-of-day distributions for United States with emphasis on California and includes comparator evidence from other countries. Across the U.S., commuting in 2022 still looked very different from before the pandemic: driving alone rose slightly to 68.7% but remained well below 2019 levels (75.9%), and public transit use recovered only to 3.1% after dropping to 2.5% in 2021. Working from home stayed far higher than before the pandemic at 15.2% (up from 5.7% in 2019), contributing to roughly 9 million fewer commuters traveling during peak morning hours compared with 2019. Average one-way commute times increased to 26.4 minutes, still below the 2019 peak of 27.6 minutes[1]. In parallel, national vehicle travel has largely recovered and slightly exceeded pre-pandemic totals: 2019 total VMT is reported as 3,261,772 million miles[2], while it is 3,294,031 million miles for 2024[3] (~1% above 2019) and 3,323.786 million miles for 2025[4] (~1.9% above 2019). This combination persistently higher telework with recovered VMT implies that non-work driving and dispersed destination patterns are important offsets, and peak-period congestion pressure can fall even when total VMT returns, consistent with observed peak spreading on California freeways and evidence of lower delay[5].

For ABMs, the evidence points to high-value recalibration targets that directly affect statewide and regional planning outputs (e.g., VMT-reduction strategy assessment, infill program benefits, and SCS/SB 375 policy packages). A completed UC Davis study found that COVID-19 caused a major shift in California from in-person commuting to remote and hybrid work, increased vehicle ownership, and a surge in online shopping, especially among higher-income and urban residents. While some of these changes are temporary, others like hybrid work and greater car dependence may have lasting impacts on transportation, equity, and urban planning in the state. Policy recommendations that may affect ABMs include supporting equitable access to remote work, rethinking transportation planning, promoting sustainable mobility, and helping cities and retailers adapt to new shopping and travel patterns[6].

## Planning context for SCS, SB 375, CEQA VMT, and model credibility

SB 375 requires that metropolitan planning organizations prepare a Regional Transportation Plan (RTP)/SCS and that California Air Resources Board (CARB) set and periodically update regional passenger-vehicle Greenhouse Gas (GHG) reduction targets. CARB notes that targets must be updated no later than 2026[7]. This timing intersects with post-COVID behavioral persistence: if telework and dispersed travel relationships are misrepresented, SCS evaluations can systematically misstate both expected VMT and GHG performance and the incremental effects of land-use and Transportation Demand Management (TDM) strategies intended for statewide climate goals. An ongoing UC Davis research project, running through 2026, is examining how post-COVID travel patterns continue to evolve and whether California's transportation and land-use policies still align with current behavior. By analyzing 2019 - 2024 data, the team is assessing whether travel has become more localized, how well complete community models function today, and how hybrid work is reshaping job-housing balance. The work aims to provide state and regional agencies with up-to-date evidence to recalibrate SCS and related policies as travel behavior continues to shift[8]. Researchers at UCLA are also synthesizing the latest evidence on post pandemic travel patterns and interviewing transportation leaders and equity advocates to identify how California's transportation policies,

[1] https://www2.census.gov/library/publications/2024/demo/acsbr-018.pdf
[2] https://www.fhwa.dot.gov/policyinformation/statistics/2019/vm2.cfm
[3] https://www.fhwa.dot.gov/policyinformation/statistics/2024/vm2.cfm
[4] https://rosap.ntl.bts.gov/view/dot/88975/dot_88975_DS1.pdf
[5] https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0290534
[6] https://escholarship.org/uc/item/0xm768km
[7] https://ww2.arb.ca.gov/our-work/programs/sustainable-communities-program/sb-375-regional-targets
[8] https://ucits.org/projects/do-existing-policies-still-hold-quantifying-enduring-post-covid-travel-patterns-and-calibrating-policies/

investments, and planning frameworks should evolve to reflect new travel realities while still advancing environmental sustainability and equity[9]. Another ongoing project on categorizing and prioritizing trip types aims to refine how the state measures and reduces VMT to meet climate goals under SB 375. Instead of treating all VMT as equal, the research examines how different trip purposes and vehicle types contribute differently to environmental and economic outcomes[10].

On the project delivery and California Environmental Quality Act (CEQA) side, Office of Planning and Research (OPR)'s SB 743 Technical Advisory established VMT as the significance metric replacing Level of Service (LOS) in CEQA transportation impact analysis (with accompanying methodological recommendations and thresholds/mitigation framing)[11]. Because SB 743 implementation increasingly relies on regional and statewide modeling systems (e.g., ABMs), post-2019 shifts in OD patterns and trip timing can materially change a project's VMT context (e.g., whether trips are longer and more interregional, and whether peak vs. off-peak shares differ affecting operational strategies and induced travel estimates). The June 2025 Transportation Trends Report shows that the Southern California Association of Governments (SCAG) region's travel patterns are experiencing an uneven but ongoing post-pandemic recovery, with bus ridership reaching 76%, light and heavy rail 74%, and commuter rail 63% of pre-pandemic levels, all exhibiting strong seasonal swings and generally slower winter performance. Roadway activity has rebounded more fully, with VMT at 97% of pre-pandemic levels, while vehicle hours of delay (VHD) remain at only 71%, suggesting that widespread remote and hybrid work (averaging 34% of workdays at home) continues to suppress peak-period congestion. Truck VMT, a proxy for goods movement, has stabilized at about 95% of pre-pandemic levels following a pandemic-era surge. Overall, the report highlights that while travel demand is rising, structural shifts in commute behavior and telework continue to reshape congestion patterns, transit ridership recovery, and long-term transportation planning in the region[12].

A key institutional constraint is that many regional models have not undergone full post-pandemic recalibration. A report evaluates how well California's regional Travel Demand Models (TDMs) primarily developed by MPOs and Regional Transportation Planning Agencies (RTPAs) for long-range planning, air quality conformity, and SB 375 compliance can support Caltrans project-level forecasting needs. It finds that they are generally unsuitable for project-level analyses due to outdated base years, limited documentation, insufficient calibration and validation (especially for peak periods), lack of project-level sensitivity testing, inadequate representation of induced VMT, incomplete or static sub-modules (e.g., freight, visitors, airport), and the absence of dynamic traffic assignment. The report highlights that most California regional TDMs remain aligned with pre-COVID travel behavior. Only about 10% of agencies have performed post pandemic recalibration, and just 37% have implemented any COVID related adjustments, despite substantial long-term changes in travel such as increased teleworking, altered peak hour patterns, reduced transit ridership, and shifts in shopping and commuting behavior. The study emphasizes that outdated base years mean current models fail to reflect persistent post COVID conditions, causing inaccuracies in peak hour volumes, VMT forecasts, and induced travel estimation. Agencies also noted that pandemic driven trends like peak spreading, higher delivery activity, and remote work are not adequately captured by existing models[13]. This creates a direct policy risk: SCS strategy packages and CEQA VMT mitigation approaches may be evaluated with behavioral parameters that no longer match observed telework intensity, destination patterns, and time-of-day distributions.

A report explains how the Covid-19 pandemic dramatically reshaped urban mobility, disrupting travel patterns, accelerating telework, exposing inequalities, and highlighting both the vulnerability and

[9] https://ucits.org/projects/do-post-pandemic-travel-shifts-warrant-changes-to-californias-transportation-policies-and-plans/
[10] https://its.uci.edu/projects/categorizing-and-prioritizing-trip-types-to-support-californias-vmt-reduction-goals/
[11] https://lci.ca.gov/docs/20190122-743_Technical_Advisory.pdf
[12] https://scag.ca.gov/sites/default/files/2025-08/26-417-MMI-0343-Transportation-Trends-Report-June-2025.pdf
[13] https://dot.ca.gov/-/media/dot-media/programs/sustainability/documents/demand-modeling/review-of-use-of-tdm-for-analysis-of-caltrans-projects-a11y.pdf

importance of public transport. Based on this report, cities worldwide saw sharp drops in transit use, rising car dependence in some areas, and major increases in walking, cycling, and micromobility as governments deployed pop-up infrastructure and reclaimed street space. Teleworking reduced commuting but introduced uncertainty about long-term travel demand, residential relocation, and emissions impacts. To guide recovery, the report urges cities to adopt a vision-led decide and provide planning approach, prioritize accessibility over mobility, reallocate space from cars to people, strengthen public and informal transport, invest in permanent active-travel networks, and improve data collection. It also emphasizes multi-level governance and sustained national funding such as integrated, low-cost transit passes to build more resilient, inclusive, and sustainable transport systems in the post-pandemic era[14].

## Empirical changes since 2019 relevant to OD, purpose, and time-of-day

Remote work has remained meaningfully elevated relative to 2019, and its persistence is measurable both in usual commute mode statistics (ACS) and in daily activity/travel surveys. The share worked from home (means of transportation to work) increased from 5.7% (2019) to 17.9% (2021) and then declined to 15.2% (2022)[15]. A subsequent Census update reported that 13.8% of U.S. workers usually worked from home in 2023 versus 5.7% in 2019, and that the number of home-based workers rose from about 9 million (2019) to more than 22 million (2023)[16]. The 2022 National Household Travel Survey reveals a marked shift in work-from-home frequency among U.S. workers compared to previous years. In 2022, only 62% of workers reported never working from home, a significant decrease from 78% in 2017. Meanwhile, the share of workers who worked from home five or more days per week rose from 12% to 19%, and those working from home one to four days per week also increased. Importantly, 70% of workers who changed their work travel due to the pandemic considered the change permanent. These trends highlight the pandemic's lasting impact on work habits, with remote work becoming a more common and enduring feature of American life, contributing to reduced commuting and overall travel activity[17].

A paper analyzes three years of German travel-survey data and finds that COVID-19 sharply increased telecommuting, especially among workers who had never worked from home before, though telework opportunities remained concentrated among highly educated, higher-income professionals. Longer commutes continued to make people more likely to choose telework, and pandemic pressures such as childcare disruptions and infection concerns made people living alone and households with young children more inclined to work from home. Both total trips and distance traveled dropped significantly in 2020, with new telecommuters showing the largest reduction in commuting. Experienced telecommuters, however, had higher non-work travel before the pandemic, suggesting that telework doesn't automatically reduce overall travel demand. Overall, the pandemic triggered larger behavioral changes for new telecommuters, highlighted persistent inequities in who can telework, and suggested that many changes particularly for new telecommuters may shift again as post-pandemic conditions normalize[18].

The pandemic caused a sharp and immediate drop in road traffic across all parts of London, with central London experiencing the steepest decline as restrictions significantly reduced travel demand. Traffic began to recover gradually through 2021 and 2022 but has not returned to pre-pandemic levels, especially in central and inner London, where 2022 volumes remained well below 2019 benchmarks. Goods vehicle traffic has recovered even more slowly than car traffic, indicating that freight activity in central and inner areas has not rebounded at the same pace. Strategic cordon counts also show incomplete recovery, with central cordon flows still 21 percent below 2019 levels in 2022. Congestion, which fell markedly during lockdowns due to lower traffic volumes, has since trended upward again as activity resumed, though it

[14] https://www.itf-oecd.org/sites/default/files/docs/shaping-post-covid-mobility-cities.pdf
[15] https://www2.census.gov/library/publications/2024/demo/acsbr-018.pdf
[16] https://www.census.gov/library/stories/2025/01/work-from-home-inequalities.html
[17] https://nhts.ornl.gov/assets/2022/pub/2022_NHTS_Summary_Travel_Trends.pdf
[18] https://journals.sagepub.com/doi/10.1177/03611981221089938

remains uncertain whether current slightly lower delay values reflect lasting demand changes or improved operational management[19].

A report outlines how working from home in Canada surged from about 7% of workers in 2016 to nearly 40% at the height of the COVID-19 pandemic in April 2020, before settling to around 20% by November 2023, reshaping commuting patterns, public transit use, and environmental impacts. Increased teleworking sharply reduced public transit ridership, both directly through fewer commuters and indirectly as lighter traffic encouraged some workers to switch to driving rather than transit. The shift also likely lowered greenhouse gas emissions from transportation, with estimates suggesting that widespread remote work could have cut emissions annually, though actual reductions are smaller since not all eligible workers telework fulltime[20].

Remote work has had wide-ranging and persistent effects on U.S. mobility patterns, emissions, and public transit systems. The results of a study show that a 1% reduction in on-site workers corresponded to a 0.99% decrease in VMT and a 2.26% decline in transit ridership, with regions that have higher shares of transit commuters showing smaller VMT impacts but larger ridership declines. The results also show that a sustained 10% decrease in on-site workers would yield substantial environmental benefits while simultaneously causing significant financial strain for transit agencies through the loss of annual fare revenue. The study also highlights that remote work adoption varies by region due to differences in industry composition and areas with more jobs suitable for remote work show much slower recovery of on-site attendance. Additionally, the analysis notes that while remote work reduces commuting, it may induce some non-work travel, though during the pandemic such induced trips were likely suppressed, suggesting the need for further research in a fully post-pandemic context. Overall, the findings emphasize that remote work can be an effective decarbonization tool, but it presents long-term challenges for the financial sustainability and service planning of public transit systems[21].

A research presents a detailed analysis of post-COVID teleworking using survey data from over 1,000 workers in the Dallas-Fort Worth and Washington D.C. regions, developing a latent class choice model that identifies five distinct motivation-based teleworker segments (travel-dominant, flexibility-dominant, career-dominant, workplace-discouraged, and family-dominant) and demonstrates that each reflects a different combination of attitudes, constraints, and lifestyle factors. The study shows that telework motives are deeply rooted in issues such as commute stress, desire for time and location flexibility, career development needs, dissatisfaction with workplace environments, and family-work conflict, with each group displaying unique demographic patterns, job characteristics, and residential contexts, such as long average commutes for travel-dominant workers, frequent suburban residence and co-teleworkers for flexibility-dominant households, and high caregiving responsibilities among family-dominant workers. Expected telework frequency also varies sharply: flexibility- and family-dominant workers anticipate teleworking three or more days per week, whereas career-dominant workers largely use telework only for occasional needs, and many travel-dominant and workplace-discouraged workers would prefer to telework more but appear constrained by workplace norms or policies. The study highlights substantial heterogeneity in how sociodemographic, job roles, attitudes, and even gender influence telework expectations (for example, education increases teleworking among workplace-discouraged and family-dominant workers but decreases it for career-dominant workers, while women telework more in family-oriented segments yet less in travel- and workplace-related ones). Overall, the study argues that telework cannot be treated as a uniform behavior and understanding these motivational segments is

[19] https://content.tfl.gov.uk/travel-in-london-2023-road-traffic-trends-acc.pdf
[20] https://www150.statcan.gc.ca/n1/en/daily-quotidien/240118/dq240118c-eng.pdf
[21] https://www.nature.com/articles/s44284-024-00057-1

essential for predicting post-pandemic travel demand and informing transportation policy, land-use planning, and employer strategies[22].

A similar study analyzes how U.S. teleworking behavior evolved before, during, and after COVID-19 using a survey finding that although telework surged during the pandemic and is expected to remain 2.6 - 3.3 times higher than pre-COVID levels, these expectations are likely over-optimistic given gaps between preferred and expected telework frequencies. It identifies eight worker segments (Climbers, Plateauers, Cappers, Stable Unables, Stable Non-Choosers, Stable Non-Usual Teleworkers, Stable Usual Teleworkers, and Reducers) each reflecting distinct telework trajectories, feasibility constraints, job types, household structures, and attitudes. Many workers who increased telework during COVID were new to it, and segments expecting sustained increases often tend to be younger, more urban-oriented, more tech-savvy, or more motivated by flexibility, while stable non-teleworkers tend to hold jobs incompatible with remote work and express less favorable attitudes toward telework. The findings suggest that teleworking will continue reshaping travel behavior, residential location choices, and vehicle ownership, and that understanding the heterogeneity among teleworkers is essential for anticipating long-term transportation and land-use impacts[23].

Another study analyzes 2022 National Household Travel Survey data shows that 29% of U.S. workers commuted less often in 2022 than before the pandemic, while 63% commuted the same amount and 8% commuted more. Among those who reduced commuting, most reported the change as permanent, with only 24% saying it was temporary and 22% unsure. Workers most likely to permanently reduce commuting were disproportionately well-educated (66.5% held a bachelor's degree or more), middle-aged (82.6% between 30 - 59), urban residents (87.6%), public transit users, and those in carless or car-deficit households (16.1% combined). Those less likely included workers with children (33.8%) and many Asian and Latino/a workers. The study also concludes that while the pandemic broadened access to remote work, the enduring remote-work population is essentially an expanded version of the small pre-COVID telework group[24].

The revised work from home assumptions for Plan Bay Area 2050+ prepared by MTC-ABAG (Metropolitan Transportation Commission and Association of Bay Area Governments) reflect new post-pandemic data showing that remote and hybrid work remain far above pre-2020 levels and are unlikely to return to historic norms. Using sources such as the ACS (American Community Survey), BLS (Bureau of Labor Statistics), SWAA (Survey of Working Arrangements and Attitudes), and especially the 2023 BATS (Bay Area Travel Study), MTC-ABAG finds that although WFH rates have declined from the 2020 peak, they have stabilized near 30 - 40%. Employer surveys indicate that most organizations have already implemented long-term hybrid policies, suggesting only small additional declines. Given uncertainty in future patterns, the plan assumes WFH will taper slightly through 2025 and then remain flat through 2050. These updated assumptions feed into Travel Model 1.6 (TM1.6) which now includes a new WFH component calibrated using 2023 BATS data and the model assigns each synthetic worker a daily WFH status and captures geographic, income, and industry patterns using TM1.6-equivalent WFH rates derived from the updated assumptions[25].

Telecommuting substantially reduces commute-related vehicle travel, though increases in non-commute trips can partially offset these savings. Evidence from multiple quasi-experimental studies shows large reductions in commute VMT on telecommuting days (often above 60 - 90%) and modest to significant reductions in total daily travel, with recent nationwide data showing about a 9% drop in daily Person Miles

[22] https://www.sciencedirect.com/science/article/pii/S0965856424001186
[23] https://www.sciencedirect.com/science/article/pii/S2214367X23000790
[24] https://www.sciencedirect.com/science/article/pii/S259019822500274X
[25] https://planbayarea.org/sites/default/files/documents/Technical_Methodology_Memo_Attachment_C_WFH_Assumptions_Revised_February_2025.pdf

Traveled (PMT). Telecommuting offers major benefits for workers (less stress, lower costs), employers (higher morale, potential space savings), and communities (lower emissions, support for local businesses), but its advantages are unevenly distributed because many lower-wage jobs cannot be done remotely, and disparities in broadband access persist. While telecommuting synergizes well with walkable and bikeable land uses, it can negatively impact transit ridership, and long-term effects (such as residential relocation farther from workplaces) introduce uncertainty about its net impact on regional VMT. Overall, research indicates meaningful VMT reductions but highlights variation by context, worker characteristics, and implementation scale[26].

A research study examines how Southern California's built environment shaped travel behavior before and during the COVID era using StreetLight mobility data for 2019 and 2021, finding that traditional placemaking factors (such as density, walkability, low-speed streets, multifamily housing, and nearby everyday destinations) continued to be strongly associated with lower VMT and a higher share of short trips even after the pandemic began. While neighborhood destinations generated more local short trips, they also attracted more overall travel, increasing total VMT. Core urban areas with high regional job accessibility showed depressed activity and lower VMT rebound in 2021, reflecting persistent telework impacts, whereas areas with many children experienced the strongest VMT rebound as school and youth activities resumed. Overall, the findings suggest that compact, walkable, 15-minute-style communities remain effective for reducing trip lengths in the COVID era, while telework's lasting influence highlights challenges for downtown vitality and transit recovery[27].

National travel activity shows a combination of fewer person trips but longer trips, consistent with fewer short discretionary errands and a different spatial distribution of travel. According to the 2022 National Household Travel Survey, Americans averaged 2.28 person trips per person per day, a sharp decline from previous years (for example, 3.37 in 2017 and 4.09 in 2001). This drop is largely attributed to pandemic-related changes, increased teleworking, and the rise in online shopping and services, which reduced the need for frequent daily travel. In 2022, the breakdown of daily trips per person included 0.42 trips for work, 0.80 for shopping and errands, 0.26 for school or church, 0.67 for social and recreational purposes, and 0.13 for other reasons. The data show that not only did the total number of trips decrease, but the reduction was most pronounced in shopping, personal errands, and school/church activities. These trends highlight a major shift in American travel behavior, with fewer but longer trips and a greater reliance on technology to substitute for physical travel[28].

The same source explicitly attributes the largest decline to personal errands. American households made an average of 364 person trips per year for other family/personal errands, a category that includes travel for everyday tasks such as visiting the post office, dry cleaners, or library. This represents a significant decrease from 628 trips per year in 2017, reflecting a shift toward fewer in-person errands, likely due to increased use of online services. Despite the reduction in trip frequency, the average length of these trips increased to 8.6 miles (up from 7.1 miles in 2017), and households traveled a total of 3,102 miles annually for these errands, down from 4,469 miles in 2017. The data suggest that while Americans are making fewer trips for routine errands, each trip tends to cover a longer distance, highlighting changes in travel patterns and the growing impact of digital alternatives[29]. These shifts are directly relevant for ABM calibration because they imply changes in tour formation and trip generation, and different trip-length distributions that can alter VMT even if trip counts decline.

A research study used large-scale location-based services (LBS) data from StreetLight to track hourly vehicle trip originations at the census block-group level across the Greater Los Angeles region during two

[26] https://ww2.arb.ca.gov/sites/default/files/2025-04/Telecommuting%20-%202025%20Policy%20Brief.pdf
[27] https://www.sciencedirect.com/science/article/pii/S0966692325001097
[28] https://nhts.ornl.gov/assets/2022/pub/2022_NHTS_Summary_Travel_Trends.pdf
[29] https://nhts.ornl.gov/assets/2022/pub/2022_NHTS_Summary_Travel_Trends.pdf

comparable periods: midweek days in October 2019 (pre-pandemic) and October 2021 (late-pandemic). Researchers analyzed more than 30 million trips in 2019 and 19 million in 2021, focusing on how trip timing shifted across the day, especially between the early PM period (12 - 3:59 PM) and late PM period (4 - 7:59 PM). The study found that the PM peak shifted earlier (from 5 PM to 3 PM) and broadened into a multi-hour plateau. The PM-peak shifted earlier because school dismissals create a concentrated surge of 2 - 4 PM trips, while widespread remote-work capability reduced traditional 5 PM commute traffic. At the same time, changes in work patterns for low-wage workers and workers of color contributed to shifting travel into earlier afternoon hours[30]. Another study shows that morning freeway traffic in six major California cities shifted from a single peak before COVID-19 to a clear double-humped pattern after the pandemic, with two distinct peaks around 6:45 AM and 7:45 AM separated by a mid-peak dip. This change is driven primarily by shifts in commuter composition: industries with high WFH capability (such as information technology, finance, education, and professional services) experienced the largest reductions in commuting, and these industries typically traveled during the middle of the morning peak. Their withdrawal created a valley between two remaining peaks formed by industries that continued commuting earlier or later in the morning. Using freeway performance data, employment data, and household travel survey data, the study finds that cities with greater commuter loss showed a more pronounced bifurcation, indicating that pandemic-related unemployment and remote work reshaped travel patterns and reduced overall congestion during peak periods[31].

Time-of-day distributions at the national level have remained broadly stable in aggregate shares, but with measurable shifts within peak periods and a persistent dominance of midday travel that complicates simple peak/off-peak assumptions. Comparing 2017 and 2022 data from Table 8-1 of the National Household Travel Survey, the distribution of person trips by start time shows some notable shifts. In 2022, the share of trips beginning during the morning peak (6 - 9 a.m.) increased to 17.8%, up from 16.6% in 2017. Midday trips (9 a.m. - 1 p.m.) decreased from 25.4% in 2017 to 23.4% in 2022, while trips starting between 1 p.m. and 4 p.m. rose slightly from 22.1% to 23.8%. The evening peak (4 - 7 p.m.) remained stable, with 22.1% in 2017 and 22.0% in 2022. Evening trips (7 - 10 p.m.) declined from 9.8% to 8.9%. Late night and early morning trips (10 p.m. - 6 a.m.) stayed consistent, accounting for 4.2% of trips in both years. Overall, these changes indicate a modest shift toward more morning travel and fewer midday and evening trips[32]. The report also states that almost half (47%) of all person trips started between 9 a.m. and 4 p.m. in 2022. These distributions imply that ABM time-of-day modules must be calibrated not only to a narrower peak but also to midday that remains the plurality, especially as hybrid-work schedules shift mandatory-tour timing and nonwork tour chaining.

Evidence from California freeway sensors indicates that although overall traffic volumes in California have nearly returned to pre-pandemic levels, traffic is now spread more evenly across the day, resulting in flatter peak periods and reduced congestion. Using data from 3,691 Caltrans sensors, the results show that the share of daily occupancy occurring during the peak hour decreased by 0.56 percentage points, a 5.5% reduction from the pre-pandemic average of 10.3%, indicating a meaningful decline in how concentrated traffic is in the busiest hour of the day. Entropy-based measures confirm this spread, and average daily congestion dropped by 14 minutes. Although patterns vary regionally, the findings suggest that traditional peak-hour based roadway planning may now overestimate future needs, potentially leading to unnecessary or oversized infrastructure investments[33]. Regional monitoring in Southern California is consistent with this direction. SCAG's June 2025 Transportation Trends report states overall VMT is at 97% of pre-pandemic levels while vehicle hours of delay have not returned to pre-pandemic levels and indicates vehicle hours of delay have reached 71% of pre-pandemic levels, alongside an annual

[30] https://rosap.ntl.bts.gov/view/dot/86812
[31] https://link.springer.com/article/10.1007/s11116-022-10329-1
[32] https://nhts.ornl.gov/assets/2022/pub/2022_NHTS_Summary_Travel_Trends.pdf
[33] https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0290534

average of 34% of workdays performed from home[34]. Total VMT recovery at the national level is now high enough that VMT-reduction strategies cannot assume that telework automatically delivers durable statewide VMT reduction without complementary land-use and pricing/operational strategies. 2019 total VMT is reported as 3,261,772 million miles[35], while it is 3,294,031 million miles for 2024[36] (~1% above 2019) and 3,323.786 million miles for 2025[37] (~1.9% above 2019). These trends show recovery not just to baseline but modest exceedance versus 2019.

A research study examines 2019 - 2022 American Time Use Survey data and finds that COVID-19 produced long-lasting shifts in how Americans allocate time, travel, and shop. Daily schedules became less fragmented during the pandemic and never fully returned to pre-COVID patterns, with people spending more time at home and less time in outdoor activities and travel even in 2022. A new Home Work Day pattern emerged due to widespread telecommuting and persisted post-pandemic, while traditional commuting days declined. Travel activity decreased overall, with lower trip durations and fewer travel modes used, though active transportation like walking and biking increased after vaccination periods. Public transit use fell in total but lengthened among those who continued using it. At the same time, online shopping increased sharply during the pandemic and remained elevated afterward, including online grocery purchasing, helping explain why travel levels did not rebound. Overall, the research shows that many behavioral changes triggered by COVID-19 (more home-centered routines, sustained telework, reduced travel, and increased e-commerce) have persisted beyond the phase of the pandemic, reshaping long-term patterns of daily life in the United States[38].

## Key quantitative findings by major source

In 2022, the National Household Travel Survey found that Americans averaged just 2.28 daily person trips per person, down from 3.37 in 2017 (a 32% decline) while the average trip length increased to 12.6 miles, up 18% from 10.7 miles. Shopping trips saw a dramatic 53% reduction in person miles traveled, and overall, households generated 37% fewer person trips and 32% fewer vehicle trips compared to 2017. Public transit use for commuting fell from 7% to 4%, and walking trips per household dropped to 136 from 329. Telework surged, with 19% of workers working from home five or more days per week, up from 12% in 2017, and the average commute trip length increased to 13.4 miles. Rideshare usage (Uber/Lyft) nearly doubled, with 17.2% of adults using these services in the past 30 days. Online shopping deliveries to households doubled since 2017, and 83% of respondents said this change was permanent. Among special populations, people aged 65+ took fewer trips and drove less, but their average trip length rose to 10.5 miles. Urban residents were twice as likely to use bicycles and 50% more likely to walk than rural residents, and micromobility modes like e-scooters and bikeshare saw increased adoption in cities. Overall, the 2022 NHTS highlights a post-pandemic shift toward fewer, longer trips, increased telework and online shopping, and evolving transportation preferences across the U.S[39].

A report based on annual ACS survey responses shows that U.S. commuting continued to reflect major post-pandemic shifts, with 68.7% of workers driving alone to work in 2022, still below the 75.9% recorded in 2019, while carpooling rose to 8.6%, nearly returning to its 2019 level of 8.9%. Public transit commuting remained sharply reduced at 3.1%, down from 5.0% in 2019, with major metros showing steep declines, including New York, which had about 700,000 fewer transit commuters than in 2019, and San Francisco, where transit commuting fell from 462,000 to 183,000 workers. Meanwhile, 15.2% of all workers worked from home (nearly triple the 5.7% share in 2019) with states such as Colorado, Washington, and the

[34] https://scag.ca.gov/sites/default/files/2025-08/26-417-MMI-0343-Transportation-Trends-Report-June-2025.pdf
[35] https://www.fhwa.dot.gov/policyinformation/statistics/2019/vm2.cfm
[36] https://www.fhwa.dot.gov/policyinformation/statistics/2024/vm2.cfm
[37] https://rosap.ntl.bts.gov/view/dot/88975/dot_88975_DS1.pdf
[38] https://www.sciencedirect.com/science/article/pii/S2214140523001664
[39] https://nhts.ornl.gov/assets/2022/pub/2022_NHTS_Summary_Travel_Trends.pdf

District of Columbia exceeding 20%, compared to 8% or less in Mississippi, North Dakota, and Puerto Rico. Average one-way commute times rose from 25.6 minutes in 2021 to 26.4 minutes in 2022, still below the 27.6-minute peak in 2019. Core-hour commuting (6 - 8:59 a.m.) totaled 83.3 million commuters in 2022 (down from 92.1 million in 2019) reflecting the continued influence of remote and hybrid work[40].

The Census Bureau's findings show that the growth of remote work has intensified existing socioeconomic inequalities. In 2023, 13.8% of U.S. workers worked from home, more than double the 5.7% who did so in 2019, even as the share declined from its 2021 peak of 17.9%. The findings show that home-based workers were older, with a median age of 43.5, and more likely to be White. They were also far less likely to live in poverty. Earnings gaps were substantial and in major metro areas such as New York and Chicago, median earnings for home-based workers exceeded $80,000, while in Houston they were under $70,000. State and county examples further illustrate inequality and in North Carolina, remote workers earned a median of $65,652, more than double the $30,664 median for public-transport commuters, and in Bronx County, NY, 39.3% of home-based workers were employed in management, business, science, and arts occupations compared with 27.6% of all workers[41].

Based on the highway Statistics reports, 2019 total VMT is reported as 3,261,772 million miles[42], while it is 3,294,031 million miles for 2024[43] (~1% above 2019) and 3,323.786 million miles for 2025[44] (~1.9% above 2019). These totals are essential for statewide policy calibration because they indicate that telework persistence alone does not guarantee sustained aggregate VMT reduction without complementary measures (pricing, land use, mode shift, trip substitution, and logistics effects).

The FTA Report No. 0268 (Effects of the COVID-19 Pandemic on Transit Ridership and Accessibility) documents an unprecedented collapse in U.S. transit use, with ridership dropping roughly 81 - 82% from 2019 to 2020 and commuter rail and commuter bus falling to 7% or less of pre-pandemic levels. Local bus service retained 28% of riders, and by September 2023 overall ridership had only recovered to 74% of 2019 levels, while service levels (measured through vehicle revenue miles) rebounded to 91%. Financial impacts were severe and fare revenues declined from $16.1B to $9.03B, and national farebox recovery rates fell from 31.7% to 18.2%, with large agencies experiencing drops of more than 40%. Workforce shortages resulted in a loss of 17,000 transit workers between 2018 and 2022, and supply-chain disruptions caused a 64% decline in bus deliveries and widespread procurement delays. Although agencies attempted to preserve service for disadvantaged communities, these populations still faced disproportionate losses of transit access. Slower ridership recovery, shrinking local and state funding, and the exhaustion of federal relief funds now leave many agencies facing a looming fiscal cliff that may force further service cuts, fare increases, and long-term accessibility challenges[45].

Using the share of suitable remote-work occupations as an instrumental variable, an analysis combined Google Community Mobility Reports, Federal Highway Administration VMT data, and National Transit Database ridership records (while controlling for unemployment, COVID-19 cases, reopening status, transit service levels, and GDP) to show that remote work had large, measurable impacts on mobility from April 2020 to October 2022. A 1% decline in onsite workers caused a 0.99% drop in state-level VMT and a 2.26% drop in Metropolitan Statistical Area (MSA) transit ridership, indicating strong causal reductions in both driving and transit use. A 10% reduction in onsite workers relative to pre-pandemic levels corresponds to 191.8 million metric tons fewer carbon dioxide ($CO_2$) emissions annually (equal to 10% of all U.S. transportation-sector emissions in 2019 (1,915.26 million metric tons)) but also results in a loss of

[40] https://www2.census.gov/library/publications/2024/demo/acsbr-018.pdf
[41] https://www.census.gov/library/stories/2025/01/work-from-home-inequalities.html
[42] https://www.fhwa.dot.gov/policyinformation/statistics/2019/vm2.cfm
[43] https://www.fhwa.dot.gov/policyinformation/statistics/2024/vm2.cfm
[44] https://rosap.ntl.bts.gov/view/dot/88975/dot_88975_DS1.pdf
[45] https://www.transit.dot.gov/sites/fta.dot.gov/files/2024-08/FTA-Report-0268-Effects-of-the-COVID-19-Pandemic-on-Transit-Ridership-and-Accessibility.pdf

2.4 billion transit trips per year and a $3.7 billion annual loss in transit fare revenue, which represents 26.7% of 2019 transit fare revenues. The marginal $CO_2$ effect varies widely across states, from 176.1 thousand metric tons per month in Texas to 47.5 thousand metric tons per month in New York, while the New York MSA alone accounts for 59.46% of all national transit fare revenue losses linked to remote work[46].

A study analyzed post-lockdown peak spreading in California traffic using data from 3,691 Caltrans mainline highway sensors recording 5-minute occupancy, flow, and speed from 2016 - 2022. The research team defined peakiness through four metrics (percentage of daily occupancy in the peak hour, percentage of daily flow in the peak hour, entropy of normalized occupancy (a measure of how evenly traffic is spread over the day, expressed in bits), and minutes of congestion (speed <50 mph)) and compared pre-pandemic (2016 - 2019) and post-lockdown (Feb - Aug 2022) periods using 10,000-iteration permutation tests that randomly reassigned days while preserving day-level correlation. Using these methods, they found that peak-hour occupancy decreased by 0.56 percentage points (a 5.5% reduction), entropy increased by 0.0266 bits (daytime entropy +0.0201 bits), and daily congestion fell by 14 minutes per sensor, all statistically significant, while flow showed no significant statewide change due to reduced gridlock allowing more vehicles to pass during peak periods. Though results vary geographically, with most large metro areas showing substantial reductions in peakiness, 58% of sensors exhibited meaningful peak spreading, confirming a broad, persistent flattening of rush-hour traffic across California[47].

Transit activity in the SCAG region shows an uneven but continuing recovery and by June 2025, bus ridership had reached 76%, light and heavy rail 74%, and commuter rail 63% of pre-pandemic levels, with June representing a seasonal low across all modes. Vehicular travel, however, has nearly fully rebounded (regional VMT reached 5.8 billion miles (about 97% of pre-pandemic levels)) while congestion remains significantly reduced, with vehicle hours of delay at only 71% of pre-COVID conditions, reflecting persistently lower peak-period demand. Goods movement remains strong but slightly below historical norms, with truck VMT averaging 95% of pre-pandemic volumes and fluctuating between 216 - 247 million miles over the year. A major driver of these trends is the stability of remote work and full paid workdays conducted from home averaged 34% from July 2024 to June 2025, helping suppress congestion and limiting full transit recovery despite rising travel demand overall[48].

A report finds that WFH levels in the Bay Area remain far above pre-pandemic norms, rising from 5.6% (ACS) and 11.2% (Plan baseline) in 2015 to pandemic-era peaks of 54.2% - 41.2% in 2020. Although WFH has declined since then, post-pandemic levels remain elevated, with 33.0% (ACS) and 38.1% (BLS) in 2021, 24.9% (ACS) and 33.8% (BLS) in 2022, and in 2023 ranging from 18.5% (ACS) to 34.6% (BLS), with the 2023 Bay Area Travel Study measuring 30.7%. Using a logarithmic trend derived from SWAA data (e.g., 46.3% in 2020, 40.1% in 2021, 38.7% in 2022, 36.9% in 2023), planners project WFH to decline slightly through 2025 before stabilizing at roughly 35.4% from 2035 through 2050, more than double the original Plan Bay Area 2050 baseline of 12.5% - 14.6% for 2025 - 2050. Employer surveys show stabilization as well, with 87% of employers having long-term remote/in-person policies in place by late 2023 and 98% by May 2024, supporting the assumption of a long-term plateau[49].

A study draws on both a multi-year California Mobility Panel (2018 - 2023) and a set of in-depth interviews conducted in 2024 with 38 low-income respondents, selected through a structured sampling frame based on household income and prior survey participation, to understand how disadvantaged communities are experiencing the post-pandemic new normal. Findings show that many low-income residents have

[46] https://mobility.mit.edu/biblio/zheng-impacts-remote-work-vehicle-miles-traveled-and-transit-ridership-usa/
[47] https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0290534
[48] https://scag.ca.gov/sites/default/files/2025-08/26-417-MMI-0343-Transportation-Trends-Report-June-2025.pdf
[49] https://planbayarea.org/sites/default/files/documents/Technical_Methodology_Memo_Attachment_C_WFH_Assumptions_Revised_February_2025.pdf

limited access to remote-eligible jobs, resulting in continued exposure risks during the pandemic and reduced flexibility today, while their essential activity patterns (work, school, groceries, and medical appointments) remain highly constrained. Transportation challenges persist across modes. For example, public transit suffers from low frequency, limited coverage, safety and cleanliness concerns, especially in suburban and rural areas. Walking and biking are hindered by poor infrastructure and road safety issues and micromobility and ride-hailing options are often too expensive or not available at all. Rising gas prices strain car-dependent households, prompting behavioral adaptations such as reducing nonessential trips, carpooling, using delivery services, and seeking more fuel-efficient vehicles despite affordability barriers. New and emerging technologies including hybrids, EVs, shared mobility services, and autonomous vehicles are widely perceived as unaffordable, inaccessible, or untrustworthy, particularly due to charging limitations for renters and poor connectivity in rural areas. Overall, residents consistently express a desire for more frequent, cleaner, safer, and more reliable transit, improved pedestrian and bicycle infrastructure, better road maintenance, and lower and more stable transportation costs[50].

## Evidence for ABM recalibration and applied policy calibration case studies

Telecommuting as a Structural Shift

A thesis examines how the COVID-19 pandemic dramatically accelerated the adoption of telecommuting and other Information and Communication Technology (ICT)-based activities, creating lasting changes in daily routines and travel behavior. It identifies a key limitation in existing activity-based travel demand models (the skeleton assumption, which treats work as a fixed, location-based anchor of the daily schedule) and shows that this assumption no longer reflects modern, flexible telecommuting patterns. Through multiple empirical studies using surveys and advanced econometric models, the dissertation demonstrates how telecommuting expanded during the pandemic, how attitudes and latent factors shape workplace choice, how time allocation across activities shifted, and why many workers intend to continue telecommuting long after the pandemic. Overall, it argues that telecommuting has become a permanent component of travel behavior and must be fully integrated into future scheduling models and transportation policies[51].

Another dissertation develops advanced econometric models to better understand how individuals generate and schedule daily activities, with a special focus on the impact of telecommuting. Using detailed travel survey data from British Columbia, the research introduces innovative modeling techniques that capture the interdependencies between activity participation, travel mode, timing, and destination choices at a granular, episode-by-episode level. The findings reveal that telecommuters tend to engage more frequently and for longer durations in non-mandatory activities such as shopping and recreation compared to non-telecommuters, and may also generate more non-work travel, challenging the assumption that telecommuting always reduces travel demand. The study also shows that long-term exposure to tele-activities during the pandemic increases the likelihood of continued engagement in online work and shopping. Overall, the dissertation provides new insights into the behavioral effects of telecommuting and offers practical recommendations for transportation policy, emphasizing the importance of considering land use, accessibility, and the broader impacts of flexible work arrangements in travel demand forecasting[52].

Activity Pattern Changes

A paper proposes an interpretable machine-learning framework, called Dynamic Activity Chain Pattern Estimation (DACPE), to understand how people's daily activity and travel patterns shifted during the

[50] https://postcovid19mobility.ucdavis.edu/sites/g/files/dgvnsk9331/files/media/documents/Webinar%20SB1%20DAC%202024_07-09.pdf
[51] https://www.proquest.com/openview/5d0fda4a377e35e0ddf0ef630c5c27a1/1
[52] https://open.library.ubc.ca/soa/cIRcle/collections/ubctheses/24/items/1.0443912

COVID-19 pandemic by integrating two heterogeneous data sources (detailed pre-pandemic activity-chain data from the 2017 National Household Travel Survey and daily aggregated mobility changes from Google's Community Mobility Reports). The framework first establishes baseline travel-behavior parameters using a computational-graph nested logit model, then estimates day-to-day deviations in activity engagement via a constrained optimization method and finally forecasts mobility trends using a Long Short-Term Memory (LSTM) network. Applied across multiple U.S. states, the method successfully captures major behavioral shifts (such as reduced workplace and park visits, increased stay-at-home patterns, and relatively stable grocery trips) revealing both nationwide trends and region-specific differences. The results demonstrate that combining interpretable econometric models with machine learning can effectively infer unobserved behavioral adjustments and support transportation planning and policy decisions during and after public emergencies[53]. The paper's key takeaway for updating activity-based travel demand models is that post-COVID calibration can incorporate dynamically estimated shifts in activity-location preferences to reflect how activity chain participation (e.g., work, home, grocery, park) fundamentally changed during the pandemic.

Another paper proposes a multi-day, needs-based activity and travel demand model that grounds behavior in psychological need satisfaction rather than empirically replicated patterns or ad hoc utilities. It models needs as psychological inventories that grow when unmet and are replenished through activities, with individuals optimizing participation, duration, and location choices across multiple days while balancing inventory benefits against time, travel cost, and safety-stock constraints. As part of its motivation, the paper notes that even in the post-COVID era, remote and hybrid work patterns which expanded significantly during pandemic conditions may persist and substantially reshape travel demand, reinforcing the need for models that capture flexible, nontraditional activity patterns. To achieve tractability, the authors reformulate the deterministic optimization as a mixed-integer conic program and introduce computational enhancements, such as piecewise-linear approximations and a custom solution algorithm, that dramatically reduce computing time. The accompanying empirical model introduces heterogeneity, stochasticity, and maximum-likelihood estimation, and numerical experiments show both scalability and parameter recovery. Overall, the framework offers a more behaviorally grounded, policy-sensitive approach to modeling multi-day activity and travel behavior[54].

Another interesting paper introduces a method to enrich activity-based travel demand models by adding realistic in-home activities, addressing the long-standing limitation that most ABMs only represent out-of-home behaviors. Using U.S. time-use data, the authors build statistical models (multinomial logit for activity type and log-linear regression for duration) to predict detailed in-home activity sequences within each home period, enhance these predictions using activity-sequential information to correct implausible orderings, and then calibrate results using a Simultaneous Perturbation Stochastic Approximation (SPSA) algorithm so that predicted participation rates and time-use distributions match observed marginal statistics. When applied to more than six million ABM-generated schedules in Flanders, Belgium, the method significantly improved accuracy demonstrating strong potential for integrating realistic in-home behaviors into ABMs for applications in energy modeling, emissions analysis, telecommuting studies, and sustainable policy evaluation. COVID-19 is used in this paper to argue that modeling in-home activities is now more important than ever for ABMs, as occupancy patterns and time-use behaviors have changed substantially since the pandemic[55].

Regional Travel Models

The state of activity-based modeling practice in the United States paper reviews how activity-based travel models have matured and become widely used across major U.S. regions, tracing the development of

[53] https://doi.org/10.1016/j.trc.2021.103361
[54] https://arxiv.org/abs/2312.15373
[55] https://doi.org/10.3390/su162210086

frameworks like DaySim, CT-RAMP, TourCast, CEMDAP, and ActivitySim. It highlights that post-COVID shifts (especially persistent remote work, altered peak periods, reduced transit use, and increased e-commerce) have significantly changed daily travel patterns and weakened traditional home-work relationships, requiring recalibration of existing models. Despite their advantages, activity-based models still face adoption barriers such as software complexity, limited agency resources, and challenges interpreting microsimulation outputs, prompting the authors to outline research needs for improving forecasting, dynamic assignment integration, and modeling of online in-person activity interactions[56].

In *A Snapshot of Travel Modeling Activities* (2023 Update report which was created to understand how major U.S. planning agencies have updated and improved their travel demand models since earlier reviews in 2008 and 2011), COVID-19 is highlighted as one of the biggest challenges to forecasting travel. Because of these sudden shifts, MPOs had trouble finding a normal year to use as a baseline for their models. Some used older pre-COVID data, others blended old and new data, and some waited for fresh surveys to understand how behaviors changed long-term. Agencies also added telecommuting into their models but had difficulty estimating who could or could not work remotely. Transit forecasts were especially hard to adjust because ridership dropped so drastically. Overall, COVID-19 made it clear that travel behavior can change quickly and unexpectedly, so MPOs now rely more on scenario planning rather than depending on a single forecast to understand long-term shifts in commuting, transit use, and daily travel behavior[57].

The Gen3 Model is an activity-based travel demand forecasting model developed for the Metropolitan Washington region, built on the ActivitySim platform. Unlike traditional trip-based models, Gen3 simulates travel choices at the individual and household level, capturing daily activity patterns, long-term decisions, and detailed travel behavior. Telework and WFH are explicitly represented and a binary logit module determines whether a worker is a full-time WFH employee, while a multinomial logit module predicts the frequency of telecommuting for those with a regular workplace. These modules are integrated into the synthetic population and influence trip generation, mode choice, and overall travel patterns. Gen3 is highly sensitive to changes in telework and WFH policies, employer practices, and external factors such as pandemics or shifts in regional policy because it models these choices at the person and household level and incorporates variables like time-of-day, accessibility, and individual income[58].

Similarly, Chicago Metropolitan Agency for Planning (CMAP)'s ActivitySim ABM includes dedicated modules for WFH and telecommuting frequency to accurately reflect modern work patterns, especially in light of post-pandemic changes. The WFH model, run before workplace location choice, determines whether a worker works from home or not, using factors such as job accessibility, household composition, income, and age. Full-time workers and low-income individuals are less likely to work from home, while older workers and females with preschool children are more likely. The telecommute frequency model predicts how often a worker with a regular out-of-home workplace telecommutes, considering variables like presence of children, household structure, employment status, income, auto ownership, and commute distance[59]. These documents are valuable because they describe how telework is operationalized as a behavioral choice rather than an exogenous subtraction of commute trips.

A presentation describes how post-COVID shifts necessitated retrofitting the existing TM 1.5 tour-based travel model. The proposed approach inserts a simple WFH choice model between workplace location choice and daily activity pattern generation, allowing the model to distinguish in-person, hybrid, and fully remote workers while preserving the underlying constrained structure. Using ACS Public Use Microdata

[56] https://doi.org/10.1016/j.tranpol.2025.04.020
[57] https://rosap.ntl.bts.gov/view/dot/74282
[58] https://www.mwcog.org/assets/1/6/Gen3_Model_Phase_2_Model_User_Guide_final.pdf
[59] https://cmap.illinois.gov/wp-content/uploads/dlm_uploads/CMAP_ActivitySim_ABM_Technical_Description.pdf

Sample (PUMS) and related datasets, the team estimated WFH likelihoods by income, industry, and county, then added a scaling factor to reconcile definitional gaps between ACS and travel diaries. Even with these improvements, transit ridership remained too high in calibration leading to the introduction of a post-COVID mode-preference adjustment to reflect reduced transit use among infrequent hybrid commuters[60]. This is particularly relevant for California regions with mature ABMs that cannot be fully re-estimated immediately but must improve predictive accuracy for SCS and CEQA-supporting analyses.

The revised Bay Area WFH assumptions update the travel model to reflect new evidence that post-pandemic remote work remains far higher and more persistent than originally forecast in Plan Bay Area 2050. Using SWAA time-series data, the 2023 Bay Area Travel Study, and employer return-to-office surveys, MTC-ABAG now projects that WFH rates, after declining from their 2020 - 2021 peak, will level off near a long-term plateau rather than returning to pre-COVID levels. A trend line derived from SWAA data is applied to the 2023 Bay Area Travel Study (BATS) baseline (30.7%), with WFH held constant after 2025, resulting in an estimated long-term rate of roughly 35% (significantly higher than the original 12 - 15% assumption). Travel Model 1.6 incorporates a new sub-model that assigns daily WFH behavior based on individual characteristics from BATS data. The update also interacts with policy strategy EN7 (Expand Commute Trip Reduction Programs at Major Employers) which boosts WFH rates in high-auto workplace super-districts. However, because the revised baseline is already elevated, EN7 now has less remaining capacity to increase WFH levels toward its maximum targets[61].

The Review of Travel Demand Models for Caltrans Projects Analysis examines how well California's regional travel demand models support Caltrans project-level forecasting. A key emphasis of the report is that most regional models were developed before the COVID-19 pandemic and therefore do not reflect the major shifts in travel behavior that have occurred since (such as widespread telework, changes in commute patterns, reduced transit use, increased home delivery, and peak-spreading). Only 37% of agencies have incorporated any post-pandemic adjustments, and these are generally limited, such as updating WFH rates or calibrating to 2022 traffic counts. Most models still rely on pre-pandemic base years, meaning they may misrepresent current travel patterns, peak-hour dynamics, and long-term behavioral changes. This lack of post-pandemic responsiveness contributes to broader concerns about model adequacy for project-level use, prompting the report's recommendation for more frequent updates, improved validation, and better alignment between model capabilities and the realities of travel behavior[62].

The Assessment of California MPO Travel Demand Forecasting Models report that evaluates how well California's 18 MPO travel demand models can estimate induced VMT from highway capacity expansions also mentioned COVID-19 briefly. The report notes that most MPO models rely on pre-pandemic base years (2014 - 2019), meaning they do not fully reflect post-COVID travel behavior, especially the widespread increase in telecommuting. It also highlights that some larger MPOs have begun adjusting model assumptions to account for post-COVID remote work patterns and emphasizes that capturing these shifts will be increasingly important in future model updates because COVID-19 has permanently altered commuting and daily travel behavior[63].

[60] https://www.otdmug.org/wp-content/uploads/2024/08/ODOT-MUG-2024-WFH-Retrofit.pdf

[61] https://planbayarea.org/sites/default/files/documents/Technical_Methodology_Memo_Attachment_C_WFH_Assumptions_Revised_February_2025.pdf

[62] https://dot.ca.gov/-/media/dot-media/programs/sustainability/documents/demand-modeling/review-of-use-of-tdm-for-analysis-of-caltrans-projects-a11y.pdf

[63] https://escholarship.org/uc/item/0wc735mj

## Summary of Findings

Remote and Hybrid Work Are the Dominant Long-Term Structural Change

Remote work surged during the pandemic and has stabilized well above pre-COVID levels. Nationally, working from home remains 2 - 3 times higher than 2019 rates, with millions fewer daily commuters, reduced peak-period travel, and a persistent flattening of AM and PM peaks. In California and major metros, hybrid work patterns continue to suppress peak congestion even as total VMT returns to or exceeds pre-pandemic levels.

Total VMT Has Recovered, but Congestion Has Not

Despite elevated telework, national and California vehicle miles traveled have returned to or slightly surpassed 2019 levels. However, peak-period congestion remains significantly lower, driven by peak-spreading, altered commute timing, and reductions in the most peak-intensive industries. This decoupling of VMT and congestion reflects structural behavioral changes rather than temporary conditions.

Major Shifts in Trip Purpose and Trip Frequency

The 2022 NHTS and complementary international evidence show:

- Fewer but longer daily trips, especially due to reduced shopping/errand travel.
- Large declines in discretionary short trips, replaced in part by online shopping and delivery.
- Persistently lower transit use, with slow and uneven ridership recovery.
- Growth in midday and early-PM travel, influenced by hybrid work schedules and school dismissal patterns.

These shifts alter tour formation, trip generation rates, and trip-length distributions (critical ABM components).

Time-of-Day Profiles Have Fundamentally Changed

National and California sensor data show:

- Morning peak bifurcation (two smaller peaks rather than one),
- Earlier PM peak and broader plateau, and
- Increased entropy of daily traffic, indicating flatter distributions.

ABM time-of-day models calibrated to pre-2019 patterns will not reproduce these dynamics without recalibration.

Transit Ridership and Accessibility Remain Depressed

Transit ridership has recovered only partially (typically 60 - 75% of pre-COVID levels). Declines are steepest in rail and in large metro areas. Financial, service-level, workforce, and equity impacts threaten long-term transit viability and must be represented in transit sub-models.

Inequities in Travel Recovery and Remote Work

Remote-work feasibility is strongly tied to income, education, occupation, and race. Low-income and essential workers retain pre-COVID commute patterns and face:

- Continued transit challenges (frequency, safety, coverage),
- Rising driving costs, and

- Limited access to flexible work.

Models assuming uniform telecommuting adoption misrepresent these disparities.

Land-Use and Built-Environment Effects Persist

Evidence from California and international cities confirms:

- Compact, walkable environments continue to reduce trip lengths and support short trips,
- Downtowns and job-dense cores remain suppressed due to telework, and
- Suburban and family-oriented areas experienced the strongest VMT rebound.

These patterns reinforce the need for updated accessibility, destination choice, and mode choice calibration.

ABMs and Regional Travel Models Are Largely Out of Sync with Post-COVID Reality

Only a small share of California MPOs have recalibrated models using post-COVID data. Most rely on pre-2019 base years and lack:

- Telework choice models,
- Updated trip-purpose rates,
- Revised time-of-day travel distributions,
- Modernized validation datasets, and
- Accurate induced-travel responsiveness.

This creates direct risks for SCS evaluations, VMT analyses, and project-level forecasting.

Emerging Modeling Approaches Support Post-COVID Recalibration

Recent research proposes:

- Telework segmentation and latent-class models,
- Integration of in-home activities into ABMs,
- Machine-learning-aided estimation of activity-chain shifts,
- Multi-day needs-based activity frameworks, and
- Updated WFH sub-models in ActivitySim implementations.

These tools demonstrate how ABMs can be recalibrated to reflect updated and flexible travel behaviors.

## Gaps in Findings

Data Gaps and Measurement Limitations

**Limited availability of post-2022 observed data for many metrics:** much evidence relies on 2020 - 2022 datasets (ACS, NHTS, sensor data, SWAA). Fewer sources provide robust 2023 - 2025 measurements, creating uncertainty in separating short-term recovery from long-term behavioral change.

**Lack of California-specific continuous travel survey data:** California evidence (e.g., BATS, UC Davis panels, SCAG Trends reports) is substantive but not continuous or fully aligned in methodology, which complicates statewide calibration and longitudinal comparisons.

**Sparse empirical data on trip purpose redistribution:** while strong findings exist for remote work, fewer direct measurements quantify shifting non-work travel purposes (e.g., medical, recreation, escort, school) and how these may offset commute reductions.

**Incomplete integration of delivery/e-commerce travel impacts:** this literature report notes increased online shopping and home delivery, but available sources provide limited quantification of induced commercial VMT, freight routing changes, or household substitution patterns.

**Inconsistent definitions across data sources (WFH, telework, hybrid):** ACS, BLS, SWAA, BATS, employer surveys, and travel diaries use different definitions of working from home and hybrid frequency, creating challenges in deriving a single harmonized WFH parameter.

Behavioral Uncertainties That Remain Unresolved

**Long-term persistence of hybrid work patterns:** researchers report permanence signals, but employer, industry, and labor-market dynamics beyond 2024 remain uncertain. Hybrid scheduling variability (day-of-week clustering, partial-day telework) is under-documented.

**Residential relocation impacts on VMT:** the literature notes possible shifts (e.g., suburbanization, urban core activity loss) but lacks robust causal evidence connecting relocation patterns to long-term VMT, trip lengths, or mode shares.

**Non-work travel rebound patterns:** telecommuters may generate additional discretionary trips, but findings conflict across studies, and few California-specific longitudinal datasets quantify this over multiple years.

**Trip-chaining changes among hybrid workers:** most studies observe peak spreading and fewer commute anchors, yet there is minimal granular measurement of how flexible work alters chaining, midday errands, or short local tours.

Modeling Gaps in Current ABM/TDM Practice

**Heavy reliance on pre-COVID base years (2014 - 2019):** a report highlights that most MPO models have not undergone post-COVID recalibration and still reflect pre-pandemic behavior. This creates structural mismatch for peak period timing, commute intensity, and tour formation.

**Insufficient treatment of telework as an endogenous behavioral choice:** many models still subtract commute trips rather than structurally modeling telework decisions (industry, demographics, employer policies, day-of-week patterns). Only a few examples fully operationalize these behaviors.

**Limited representation of induced VMT mechanisms:** models rarely incorporate how remote work affects non-work travel, goods movement, or activity timing, despite evidence that these factors influence total VMT.

**Static or missing sub-modules (freight, visitor, airport, delivery):** many California TDMs lack updated freight or delivery-service modules, despite growth in e-commerce and heterogeneous goods-movement recovery.

**Lack of dynamic time-of-day rescheduling mechanisms:** peak spreading is documented widely (e.g., 3,691 Caltrans sensors), yet most ABMs do not dynamically model peak flattening or midday dominance.

Equity and Distributional Gaps

**Insufficient segmentation of WFH capability by income, race/ethnicity, and occupation:** studies show strong inequities (low-income and essential workers have limited remote work access) but most models still apply uniform or aggregate telework parameters.

**Lack of disaggregate evidence for disadvantaged communities:** this literature report includes a study indicating persistent post COVID access challenges, but there is limited statewide, quantitative measurement of mode access, reliability, safety, or affordability for low-income or rural households.

**Limited understanding of how new patterns affect transit-dependent populations:** there is extensive documentation of transit ridership decline but minimal data on how service cuts, safety concerns, and off-peak changes alter trip-making among disadvantaged riders.

Policy and Application Gaps

**Uncertain alignment between post-COVID behavior and SB 375/SCS strategies:** model inputs underlying SCS evaluations may not match current behavior and it is not clear which strategies (pricing, land use, TDM) remain effective.

**Lack of empirical sensitivity testing for VMT analysis:** few studies quantify how project-level VMT performance changes under post-COVID travel regimes (e.g., changed commute distances, altered PM peak durations, new hybrid patterns).

**Limited integration of employer policies into forecast frameworks:** employer return-to-office strategies are documented (e.g., Bay Area employer surveys), but models do not yet incorporate employer-level variability or industry-specific telework constraints.

**Gaps in translating observed changes into actionable model parameters:** the literature documents strong national and regional trends, but practical calibration targets (e.g., mandatory/non-work tour rates, midday shares, hour-by-hour temporal profiles) are not consistently available.

## Next Steps

Strengthen and Modernize the Empirical Evidence Base

**Expand post-COVID data collection to fill critical gaps:** this literature report highlights strong national and regional evidence (ACS, NHTS, BATS, sensor data) but limited California-specific, continuous, and purpose-detailed datasets. Additional data collection can include non-work travel (shopping, escort, medical, recreation), trip-chaining and midday activity patterns, e-commerce delivery patterns and commercial vehicle activity, and household-level behavioral persistence (telework permanence, tour formation changes).

**Harmonize telework and hybrid-work definitions across sources:** inconsistent definitions across ACS, SWAA, BLS, 2023 BATS, employer surveys, and travel diaries make unified calibration difficult. A standardized method is needed for defining usual WFH, hybrid frequency, and day-of-week telework patterns

**Improve documentation of disadvantaged community travel constraints:** this literature report identifies persistent inequities in remote-work access, transit reliability, micromobility availability, and overall affordability among low-income populations, but quantitative statewide data remain limited. Additional targeted surveys and qualitative data collection would fill this gap.

Update and Recalibrate Modeling Frameworks

**Conduct full post-pandemic recalibration of regional TDMs and ABMs:** this literature report states that most California regional models still rely on pre-COVID base years, with outdated commute patterns, peak periods, and telework assumptions. A recalibration effort is needed to update workplace choice, work-from-home modules, trip generation for non-work purposes, and temporal distributions (AM/PM peak restructuring, midday dominance).

**Integrate telework as an endogenous modeled choice:** this literature report mentions some ABMs that already incorporate telework choices. Replicating these structures will allow models to reflect industry-level WFH capability, household/commute characteristics, hybrid frequencies, and day-specific work patterns.

**Expand activity-based model capabilities to reflect new patterns:** key improvements include dynamic time-of-day scheduling to capture peak spreading, enhanced in-home activity modeling (important given increased home-centered time use), and multi-day activity inventory approaches to reflect flexible weekly patterns. This literature report cites multiple academic frameworks that could inform ABM enhancements.

**Improve freight and delivery modules:** given the documented surge and persistence of e-commerce, the current lack of updated delivery/freight sub-modules is a significant modeling gap.

**Develop clear calibration targets for ABMs:** this literature report provides extensive evidence on time-of-day shares, telework rates, trip-purpose shifts, and VMT changes. Translating these into explicit calibration targets (e.g., AM/PM peak values, midday shares, non-work tour rates) can be a next step.

**Document methodological adjustments clearly for future updates:** given rapid post-COVID behavioral changes, models will require more frequent updates. A transparent documentation framework can be established for data sources used, assumptions adopted, and validation processes.

Clarify Policy Implications and Applications

**Reassess SB 375/SCS performance under post-COVID behavior:** telework persistence, peak spreading, fewer overall trips, longer trip lengths, and altered commute patterns all affect SCS strategies and GHG-reduction expectations. Updated modeling inputs are necessary to avoid misestimation of policy effectiveness.

**Update VMT analysis methodologies:** because VMT context (purpose distribution, time-of-day, and trip lengths) has shifted, baseline assumptions used for project-level CEQA analysis should be re-evaluated to match observed post-COVID conditions.

**Integrate employer policies into scenario assumptions:** This literature report notes strong employer-side stabilization of hybrid work practices. Formalizing employer-policy scenarios would improve long-range planning forecasts.

Future Research

**Analyze residential relocation and long-term VMT implications:** while the literature report raises the possibility that telework may shift residential patterns, there is little quantitative evidence on how this affects VMT or mode choice.

**Quantify how hybrid work alters discretionary and non-work travel:** studies show mixed effects on non-work travel (some increases, some decreases). More detailed causal analysis is needed.

**Evaluate long-term transit recovery under new commute patterns**: given the documented transit ridership decline and structural commute changes, additional research is needed to understand service planning under prolonged hybrid work.