Regularities in mobility reorganization after structural change: Evidence across U.S. cities

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Abstract

Large urban developments can reorganize mobility over extended periods, yet it remains unclear whether different projects generate comparable temporal response dynamics. This study evaluates the similarity of temporal mobility responses across developments and examines whether their inbound distance–decay relationships persist after opening. We analyze aggregated privacy-preserving Cuebiq mobile-device data for Hudson Yards in New York City, Water Street in Tampa, and Fifth + Broadway in Nashville from January 2019 through December 2025. We construct comparable normalized monthly visitation time series for the three developments and summarize their shared temporal evolution with a pooled log-scale sigmoid. We then compare the distribution of inbound visitation over distance in two-month windows before and after each opening using log–log regressions and bootstrap confidence bands. To illustrate the broader applicability of the workflow, we also present temporal response series for eight additional developments processed using the same methodology. All three developments exhibited a similar long-term response curve toward higher normalized visitation, despite different opening dates, activity levels, and short-term fluctuations. Inbound visitation continued to decline systematically with origin distance after opening in every case. The distance–decay relationship was preserved most closely at Hudson Yards, changed modestly at Fifth + Broadway, and became flatter at Water Street. The study shifts cross-project comparison from static visitation levels to the shape of mobility responses as developments mature, providing preliminary evidence of a shared temporal pattern alongside persistent spatial distance decay. Treating opening as the beginning of demand formation, rather than its endpoint, can help planners revisit transport capacity and access as actual use matures. As the evidence base expands, comparable response patterns could help planners anticipate the evolution of mobility demand following major developments, informing the timing of transport capacity and access improvements.

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STRUCTURED ABSTRACT

Objectives: Large urban developments can reorganize mobility over extended periods, yet it remains unclear whether different projects generate comparable temporal response dynamics. This study evaluates the similarity of temporal mobility responses across developments and examines whether their inbound distance–decay relationships persist after opening.

Methods: We analyze aggregated privacy-preserving Cuebiq mobile-device data for Hudson Yards in New York City, Water Street in Tampa, and Fifth + Broadway in Nashville from January 2019 through December 2025. We construct comparable normalized monthly visitation time series for the three developments and summarize their shared temporal evolution with a pooled log-scale sigmoid. We then compare the distribution of inbound visitation over distance in two-month windows before and after each opening using log–log regressions and bootstrap confidence bands. To illustrate the broader applicability of the workflow, we also present temporal response series for eight additional developments processed using the same methodology.

Findings: All three developments exhibited a similar long-term response curve toward higher normalized visitation, despite different opening dates, activity levels, and short-term fluctuations. Inbound visitation continued to decline systematically with origin distance after opening in every case. The distance–decay relationship was preserved most closely at Hudson Yards, changed modestly at Fifth + Broadway, and became flatter at Water Street.

Novelty: The study shifts cross-project comparison from static visitation levels to the shape of mobility responses as developments mature, providing preliminary evidence of a shared temporal pattern alongside persistent spatial distance decay.

Practical Applications: Treating opening as the beginning of demand formation, rather than its endpoint, can help planners revisit transport capacity and access as actual use matures. As the evidence base expands, comparable response patterns could help planners anticipate the evolution of mobility demand following major developments, informing the timing of transport capacity and access improvements.

INTRODUCTION

Large-scale urban developments reorganize destinations, public spaces, employment, and activity concentrations. Their mobility consequences affect transit service, pedestrian access, curb operations, parking, and the evaluation of major public and private investments. Research on the built environment has linked density, land-use diversity, street design, destination accessibility, and transit proximity to travel behavior (Ewing and Cervero 2010). Mobile-phone studies have also identified regularities in individual movement and aggregate trip distributions (Gonzalez, Hidalgo, and Barabasi 2008; Song et al. 2010; Barbosa et al. 2018). Together, these literatures explain important spatial features of mobility, but provide less guidance on how activity evolves through time when a large destination begins operating.

The time dimension matters because an opening date marks the beginning of operation, not the point at which a development has fully matured. Tenant occupancy, construction phases, programming, visitor awareness, and connecting transportation services continue to evolve over months or years. Individual activity spaces also vary systematically over monthly time scales (Järv, Ahas, and Witlox 2014). Mobility response is therefore dynamic and long term, and its temporal shape provides a basis for comparing how otherwise different projects evolve after opening.

The search for comparable response shapes is motivated by broader regularities in urban mobility. Human interactions scale systematically with city size (Schläpfer et al. 2014), while visitation frequency, travel distance, and destination attractiveness exhibit a common population-level relationship (Schläpfer et al. 2021). These spatial regularities suggest that normalized temporal response patterns may also provide a useful basis for comparing projects whose absolute visitation levels are not directly commensurate.

This study evaluates Hudson Yards in New York City, Water Street in Tampa, and Fifth + Broadway in Nashville using a common processing framework. The objective is twofold: to identify whether normalized visitation follows a similar multi-year temporal pattern across the three developments, and to determine whether the relationship between inbound visitation and origin distance persists after opening. The analysis combines monthly response time series with spatial distance gradients to compare both the evolution and geographic reach of mobility associated with each development. To illustrate the broader applicability of the workflow, Appendix A presents temporal response series for eight additional developments processed using the same methodology.

DATA AND METHODS

Study design, cases, and data

The study applies the same longitudinal workflow to mobile-device data for three mixed-use developments in distinct U.S. metropolitan contexts (Table 1). Opening month provides the temporal reference point in each case. The temporal analysis covers January 2019 through December 2025, yielding 84 monthly observations per case. The spatial analysis uses two complete months before and two complete months after opening, excluding the opening month itself so that each window represents a consistent operating condition.

The three developments differ in scale, program, and urban context. Hudson Yards is a roughly $25 billion, 28-acre mixed-use district built largely on platforms above active rail yards on Manhattan's West Side. Its approximately 12 million square feet of development combine offices, housing, retail, cultural facilities, and public space, extending Midtown Manhattan westward. Water Street Tampa is a roughly $3.5 billion, 56-acre waterfront district comprising approximately 9 million square feet of mixed uses. The project was planned to reconnect Tampa's central business district with the waterfront through a walkable neighborhood integrating residential, commercial, hospitality, and public-realm investments. Fifth + Broadway is an approximately $430 million redevelopment of the former 6.2-acre Nashville Convention Center site. It combines retail and entertainment space, offices, housing, and the National Museum of African American Music to strengthen downtown Nashville as a destination for residents and visitors. These differences make the cases useful for comparing response patterns across developments with distinct absolute visitation levels and geographic reach.

TABLE 1: Study Cases and Comparison Windows

Development	City	Opening month	Before / after windows
Hudson Yards	New York City	March 2019	Jan.–Feb. / Apr.–May 2019
Water Street	Tampa	April 2021	Feb.–Mar. / May–June 2021
Fifth + Broadway	Nashville	March 2021	Jan.–Feb. / Apr.–May 2021

We use aggregated, privacy-preserving mobile-device observations provided by Cuebiq (Cuebiq 2026). Each case has a target geography representing the development and a surrounding local control geography. The temporal files report daily devices observed in both geographies. The origin–destination files report aggregated inbound trips, including the date, origin grid cell, and number of trips whose destination lies within the target. Mobile-device panels are not population censuses and may vary with ownership, consent, and observation frequency (Wesolowski et al. 2013); the analysis therefore emphasizes within-case change and uses the control geography to account for changes in the observable device population.

Constructing comparable temporal response curves

The temporal analysis proceeds in three stages. First, for case c and day t, target and local-control device counts are summed separately within a centered 28-day window. The target total is then divided by the control total. The four-week window balances the weekday and weekend composition of the observations and reduces day-to-day volatility. The rolling ratios are subsequently averaged by calendar month, maintaining one monthly series for each case.

Second, two within-case normalizations support complementary comparisons. Intervention-centered indices divide each monthly ratio by its value in the opening month, so values report change relative to a case-specific opening baseline. For the pooled comparison in Figure 1, target-to-control ratios are adjusted for the relative target and control areas and divided by the case-specific 90th percentile over the full observation period. This scaling places the three time series on a common vertical range while retaining their calendar-time evolution.

Third, the scaled monthly observations are pooled and summarized with a four-parameter sigmoid fitted to the log normalized response:

$$\log y_t = \alpha + \beta \left[\frac{1 + \tanh\{r(t-\tau)/2\}}{2} \right], \tag{1}$$

where α is the lower log level, β is the change between lower and upper log levels, τ is the transition midpoint, and r controls the transition rate. Parameters are estimated by robust nonlinear least squares.

Comparing visitation–distance relationships around opening

The spatial analysis measures the great-circle distance between each origin-cell centroid and the corresponding development centroid. Distance decay is an established feature of trip distributions, although fitted relationships depend on spatial scale and study context (Lenormand, Bassolas, and Ramasco 2016; Šveda and Sládeková Madajová 2023). Across the two comparison periods, occupied distance-bin centers extend from approximately 0.03 to 186.6 km at Hudson Yards, 0.23 to 786.7 km at Water Street, and 0.02 to 487.0 km at Fifth + Broadway. These ranges reflect differences in the observed catchments rather than a common sampling boundary. All samples are therefore assigned to the same logarithmically spaced bins, and Figure 2 uses the continuously occupied range shared by every case and period. This common support comprises 14 bin centers from 0.365 to 186.6 km and is displayed as 0.3–200 km.

Monthly trip counts are first multiplied by $30/d_m$, where d_m is the number of calendar days in month m, and then summed within the two-month period. This produces comparable 30-day-equivalent totals without giving longer months more weight. Post-opening totals are also scaled in proportion to contemporaneous changes in control-area device-days, making the observable device population more comparable across the two periods.

For each development and period, distance-bin visitation is modeled as

$$\log_{10} V_b = a + s \log_{10} d_b, \tag{2}$$

where V_b is the adjusted trip total and d_b is the geometric midpoint of distance bin b. Before- and after-opening regressions use the same bins within each case. The 95% confidence bands are obtained from 2,000 bootstrap resamples of the distance bins.

FINDINGS

Similarity of temporal responses

All three monthly target-to-control series showed a broad movement toward higher normalized visitation over the observation period (Figure 1a). In the month after opening, the opening-centered values were 1.114 at Hudson Yards, 1.892 at Water Street, and 1.075 at Fifth + Broadway. By December 2025, the corresponding values were 1.993, 4.481, and 1.605. Despite differences in amplitude and short-term variation, every series ended above its opening-month baseline.

The calendar-time series include the disruption and recovery surrounding 2020–2021. Hudson Yards opened before this disruption, whereas Water Street and Fifth + Broadway opened during the subsequent recovery. After case-specific scaling, the pooled curve captures the common multi-year transition from lower to higher normalized activity, while the individual series retain their distinct amplitudes and short-term fluctuations.

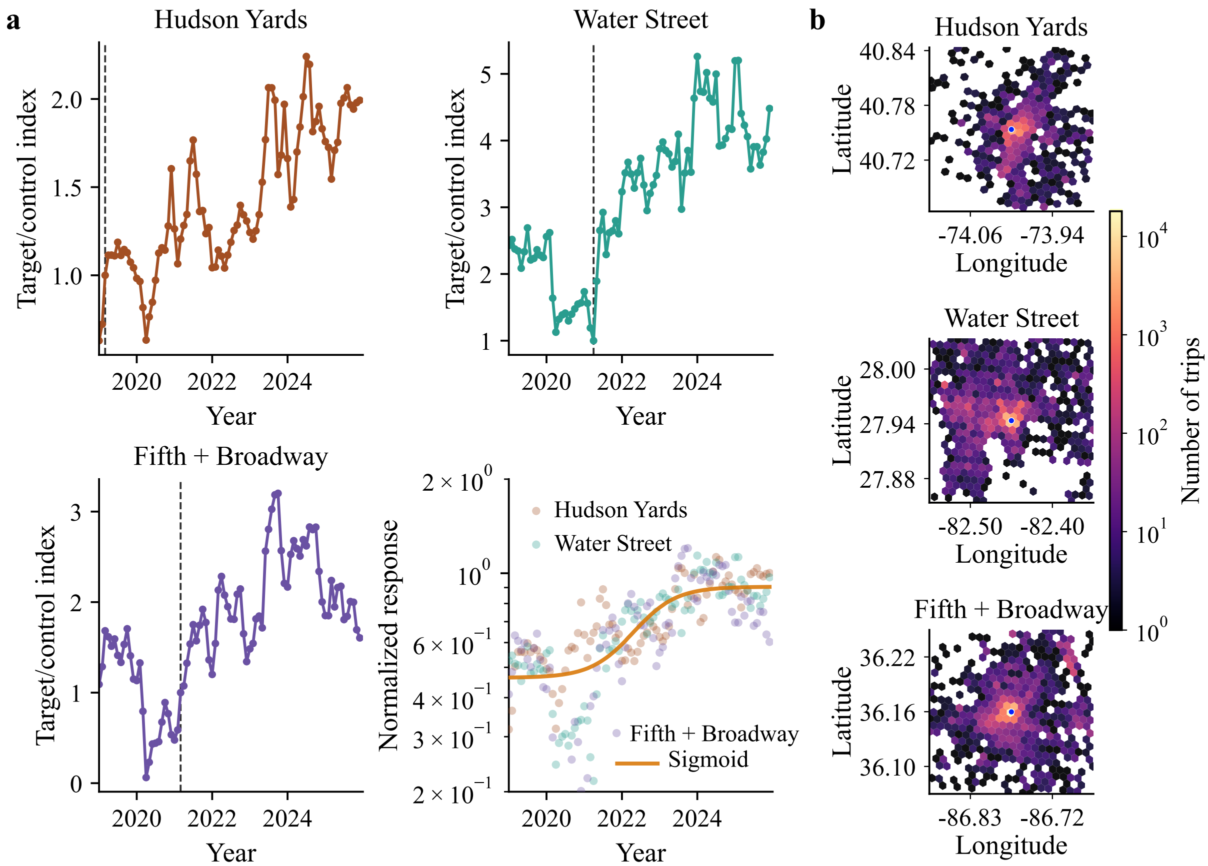

FIGURE 1: Temporal and spatial mobility patterns for Hudson Yards in New York City, Water Street in Tampa, and Fifth + Broadway in Nashville. Panel (a) presents monthly target-to-control activity indices and the pooled normalized visitation curve. Panel (b) maps inbound origin–destination trip counts from the available annual summaries. Dashed vertical lines mark each opening month.

Persistence of spatial distance decay

Control-adjusted, 30-day-equivalent inbound trip totals increased between the two-month comparison windows in all three cases: from 5,029 to 9,211 at Hudson Yards, from 2,587 to 3,441 at Water Street, and from 1,666 to 4,804 at Fifth + Broadway. Across all six case-period samples, visitation declined with origin distance over the common 0.3–200 km range (Figure 2).

The fitted slope at Hudson Yards was nearly unchanged, moving from −0.639 before opening to −0.644 after opening, while the fitted line shifted upward. Fifth + Broadway also combined an upward shift with a modest slope change, from −0.626 to −0.582. Water Street showed the largest change in gradient: its slope changed from −0.666 to −0.498, producing a flatter post-opening relationship. Thus, higher post-opening visitation was distributed across the observed distance range in all three cases, with the closest approximation to a parallel level shift at Hudson Yards and the clearest expansion toward more distant origins at Water Street.

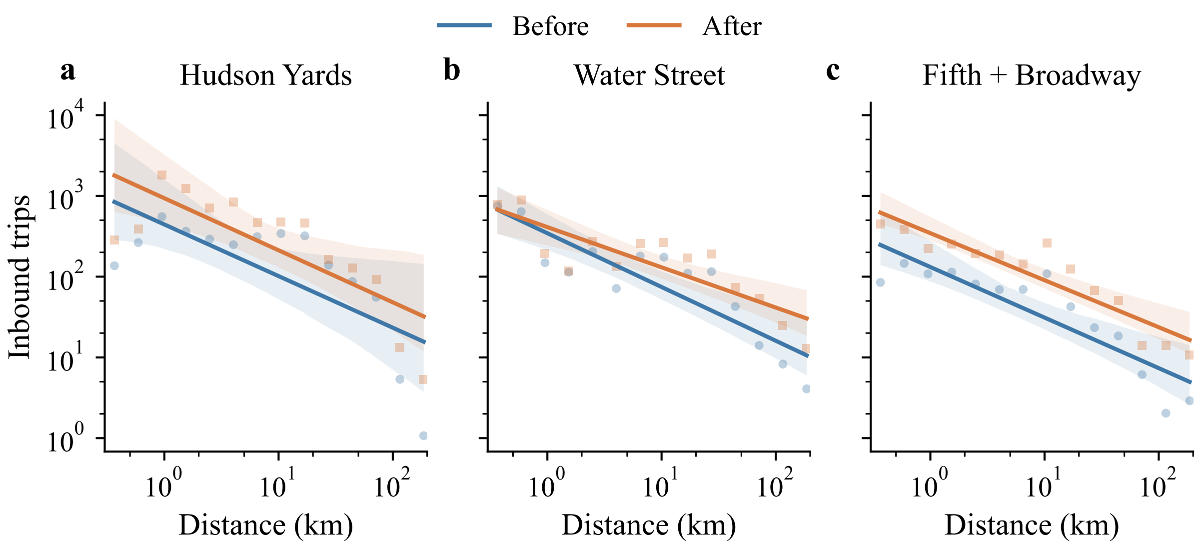

FIGURE 2: Distance decay of inbound visitation before and after opening over the common 0.3–200 km comparison range. Points show 30-day-equivalent inbound trips aggregated over two-month windows; post-opening counts are adjusted in proportion to contemporaneous change in control-area device-days. Lines and shaded bands show separate log–log regressions and 95% bootstrap confidence intervals.

DISCUSSION

The three developments exhibit a common long-run direction in normalized visitation: each moves from a lower period around the pandemic disruption toward a higher activity level by the end of 2025. This similarity appears after scaling rather than in absolute trip totals, and it coexists with different opening dates, amplitudes, and short-run fluctuations. The result complements established spatial regularities in visitation frequency, destination attractiveness, and travel distance by showing that the temporal evolution of visitation can also provide a meaningful basis for cross-case comparison.

The shared response extends beyond the direction of temporal change. In all three cases, visitation retained a systematic decline with origin distance after opening, even as its overall level increased. The developments therefore combined a similar long-term movement in normalized activity with preservation of the spatial friction that structures their catchments. The post-opening periods differed in the amount and geographic reach of visitation, but the distance–decay relationship remained. The strongest similarity across cases is consequently structural: activity progressed toward higher levels over time while nearby origins continued to contribute more visitation than distant origins.

Practical applications

An opening date is a milestone in urban development, but it is not a reliable proxy for mature travel demand. Infrastructure and service plans tied only to opening-year conditions may therefore become misaligned as occupancy, destination awareness, and surrounding activity continue to develop. Temporal response patterns make this maturation visible and provide a basis for revisiting transport capacity, access, and public-space provision as actual use evolves.

At a broader planning scale, evidence from completed developments could help planners better understand how travel demand matures following major urban projects and distinguish an expected period of demand formation from a persistent divergence that warrants investigation. As the evidence base expands, comparable mobility response patterns may help planners anticipate the pace of demand maturation, supporting the timing of transit investment, street redesign, and access improvements.

Study limitations

This initial study establishes the comparison for three developments, but the current evidence is not sufficient to define a general response pattern for large urban projects. The cases also share a study period shaped by the COVID-19 disruption, which limits separation of project maturation from wider mobility change. Future work should expand the number and types of developments, represent phased construction and occupancy more explicitly, and extend observation across successive stages of operation. Combining mobility patterns with project milestones, land-use change, transit provision, and local economic activity would help explain why response shapes converge or diverge and would test whether the observed similarity is transferable to future projects.

We further applied the same target-to-control workflow to eight additional developments spanning a wider range of metropolitan contexts and development types (Appendix A). These additional cases demonstrate that the temporal response can be consistently extracted using the same processing pipeline. A systematic comparative analysis across the expanded sample is left for future work.

CONCLUSIONS

The three developments provide initial evidence of a shared mobility structure as large urban projects mature. Each progressed toward higher normalized visitation over the observation period, while inbound visitation continued to decline with origin distance after opening. Temporal response shape and spatial distance decay therefore offer complementary measures of development maturity, connecting the evolution of activity with the geographic reach of associated travel demand. Extending this comparison to a larger and more varied set of projects could establish whether these patterns provide a transferable basis for long-term infrastructure planning.

AUTHOR CONTRIBUTIONS

Jinpeng Li: conceptualization, methodology, software, formal analysis, visualization, and writing–original draft. Markus Schläpfer: conceptualization, methodology, supervision, and writing–review and editing. Both authors reviewed and approved the manuscript.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship, or publication of this article.

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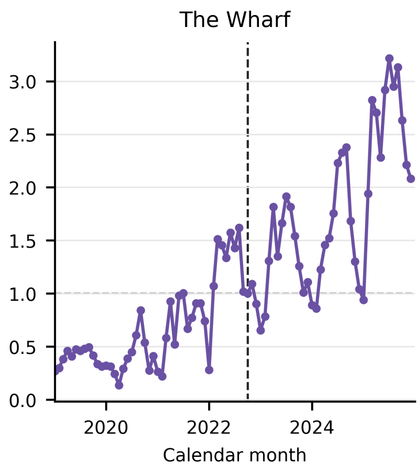
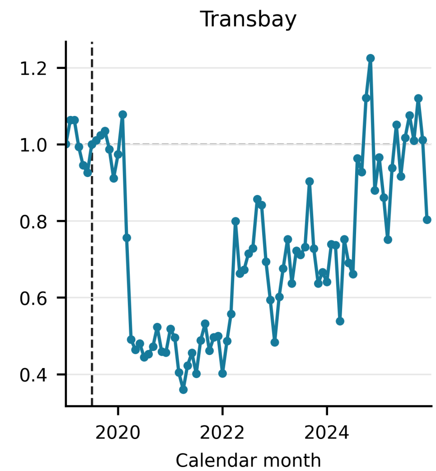
APPENDIX A: MOBILITY RESPONSE TIME SERIES FOR ADDITIONAL DEVELOPMENTS

Beyond the three cases analyzed in detail above, we applied the same target-to-control workflow to eight further large-scale developments across U.S. metropolitan areas: The Wharf (Washington, DC), Transbay (San Francisco), Chase Center Thrive City (San Francisco), Encore Boston Harbor (Everett, MA), Fashion District Philadelphia, Resorts World (Las Vegas), Scissortail Park (Oklahoma City), and Pacific Plaza (Dallas), see Figure 3. These cases span a wider range of program types — waterfront mixed-use, transit-oriented development, sports and entertainment districts, retail, gaming, and public parks — and of metropolitan contexts than the three primary cases.

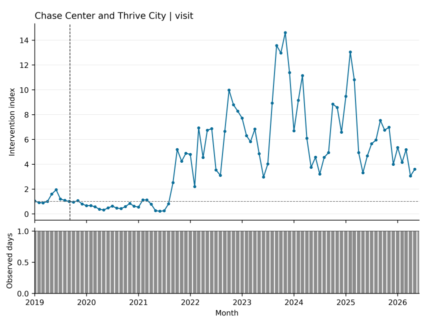
Each series exhibits a discernible before-and-after mobility response that can be extracted using the same target-to-control processing pipeline. These cases have not yet been subjected to the pooled temporal normalization or the spatial distance-decay analysis applied to the primary cases; they are presented here as evidence that the workflow generalizes across development types and as the basis for the expanded comparison described in the main text.



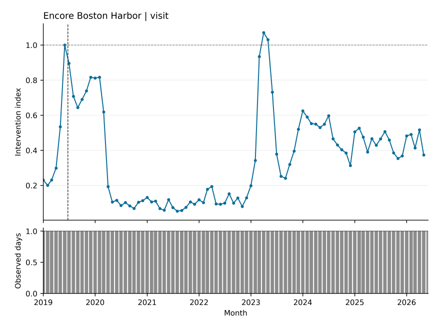
(a) The Wharf (Washington, DC)



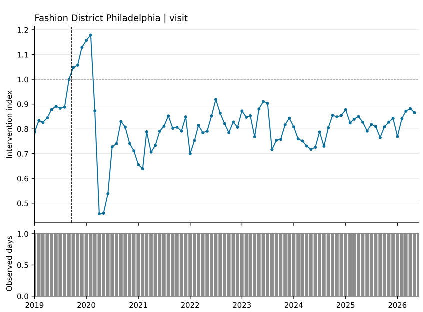
(b) Transbay (San Francisco)



(c) Chase Center Thrive City (San Francisco)

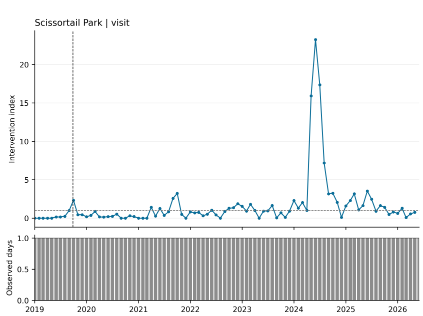


(d) Encore Boston Harbor

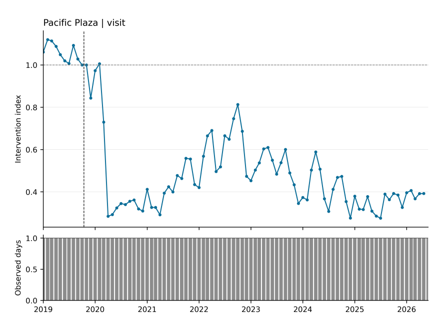


(e) Fashion District Philadelphia

(f) Resorts World (Las Vegas)



(g) Scissortail Park (Oklahoma City)



(h) Pacific Plaza (Dallas)

FIGURE 3: Temporal mobility response series for eight additional large-scale urban developments processed using the same target-to-control workflow. These cases illustrate the applicability of the processing pipeline across a broader range of development types and metropolitan contexts. They are included as supplementary evidence and have not yet been subjected to the pooled temporal normalization or spatial distance-decay analyses presented for the three primary study cases.