Supplementary Information

Overview

This PDF contains supplementary tables and figures accompanying the main article. Each item is labeled as *Supplementary Table k* or *Supplementary Figure k* and referenced in the main text accordingly. We also explicitly establish the link between items in the supplementary document (tables and figures) to the corresponding items in the main text.

Supplementary Table 1: Descriptive statistics by age group and 3-year bins, 2007–2024: Weekdays (excluding holidays). This is an extended version of Table 1 in the main text.

Supplementary Table 1. Descriptive statistics by age group and 3-year bins, 2007–2024: Weekdays (excluding holidays)

Age group	Year bin	n	Share 0 trips (%)	Avg. dist. (km)	Avg. hrs away	First trip (h)	Last trip (h)
10–17	2007–2009	3,792	7.4	14.3	8.52	8.42	17.2
18–30	2007–2009	3,992	7.9	28.9	8.75	9.23	18.3
31–55	2007–2009	11,235	7.8	36.0	8.63	8.38	17.7
56–65	2007–2009	4,669	14.0	27.3	6.44	9.16	16.9
66+	2007–2009	4,270	25.8	15.5	3.46	10.90	15.6
10–17	2010–2012	4,229	8.7	13.7	8.17	8.42	17.2
18–30	2010–2012	4,395	8.4	28.5	8.42	9.23	18.3
31–55	2010–2012	12,308	8.2	34.4	8.50	8.38	17.7
56–65	2010–2012	5,369	15.9	26.9	6.32	9.16	16.9
66+	2010–2012	5,513	28.8	14.8	3.31	10.90	15.6
10–17	2013–2015	2,028	8.6	12.8	7.88	8.42	17.2
18–30	2013–2015	2,693	9.2	29.1	8.09	9.23	18.3
31–55	2013–2015	6,323	7.0	37.6	8.59	8.38	17.7
56–65	2013–2015	2,429	13.2	28.0	6.44	9.16	16.9
66+	2013–2015	2,875	25.8	16.6	3.25	10.90	15.6
10–17	2016–2018	2,552	9.3	15.0	8.26	8.42	17.2
18–30	2016–2018	2,973	9.2	29.7	8.38	9.23	18.3
31–55	2016–2018	6,449	7.4	38.4	8.89	8.38	17.7
56–65	2016–2018	2,495	11.5	32.8	7.43	9.16	16.9
66+	2016–2018	3,378	25.1	16.4	3.68	10.90	15.6
10–17	2019–2021	1,854	10.6	13.0	7.66	8.42	17.2
18–30	2019–2021	2,980	10.9	26.5	7.72	9.23	18.3
31–55	2019–2021	5,847	8.9	33.6	8.28	8.38	17.7
56–65	2019–2021	2,149	12.4	32.6	7.19	9.16	16.9
66+	2019–2021	3,480	28.0	16.7	3.48	10.90	15.6
10–17	2022–2024	2,112	10.4	13.6	7.74	8.42	17.2
18–30	2022–2024	3,584	11.4	27.2	7.84	9.23	18.3
31–55	2022–2024	6,813	10.1	33.9	8.13	8.38	17.7
56–65	2022–2024	2,798	12.4	32.2	7.20	9.16	16.9
66+	2022–2024	4,433	25.4	15.7	3.58	10.90	15.6

"Weekdays" exclude holidays according to survey coding ($\texttt{DiaryDaytype} \in \{11, 12\}$, $\texttt{DiaryMonth} \neq 7$). Sample restricted to $\texttt{DiaryYear} \geq 2007$. "Share 0 trips" denotes the proportion of diary days with no recorded travel. Times are in hours since midnight; distances in kilometers.

Defining action-spaces from trip diaries - radial versus commutative distance. Related to Table 1 and the data-generating process in general

To construct the (d, t) state-space representation for cohort-level analysis, each person-day observation is divided into 15-minute intervals. For each interval, we record radial distance from home and cumulative travel distance, as determined from reported trip start and end points.

This expansion produces a long-format, time-resolved dataset in which each row represents a single 15-minute bin within a person-day. Table 2 shows an illustrative extract. The state space is highly sparse: most bins record zero radial distance, corresponding to periods when individuals remain stationary (typically at home).

Supplementary Table 2. Expanded microdata structure. Each row represents a 15-minute temporal bin within a person-day, with person-level attributes (SessionId, Year, Age, Cars) and time-varying state variables: radial distance from home $r(t)$ and cumulative travel distance $d(t)$. Most bins show $r(t) = 0$ (being at home), reflecting the sparse, home-anchored nature of daily mobility.

SessionId	**Year**	**Age**	**Cars**	**Time (min)**	**Radial Dist.** $r(t)$	**Cum. Dist.** $d(t)$
1001	2010	31–55	1	0	0.0	0.0
1001	2010	31–55	1	15	0.0	0.0
...	...	...	...	...	...	...
1001	2010	31–55	1	375	1.2	2.3
1001	2010	31–55	1	390	3.0	5.8
1001	2010	31–55	1	405	2.1	8.0
1001	2010	31–55	1	420	0.0	8.0
...	...	...	...	...	...	...
1001	2010	31–55	1	1410	0.0	12.5

From this sparse microdata, we estimate a smooth empirical surface $\hat{\rho}_{c,\tau}(r, t)$ representing the distribution of radial distances r over time t for each cohort c in survey year τ. This surface:

- *Interpolates* across discrete 15-minute bins,
- *Smooths* across radial distances to reduce noise from individual variability,
- *Regularizes* heterogeneous patterns into a coherent cohort-level footprint.

These cohort-level surfaces provide the input for estimating drift fields and divergence terms in the continuity equation, forming the basis for the dynamics analyzed in subsequent sections.

Our primary distance measure is the *radial action-space* $r(t)$, defined as the straight-line (great-circle) distance from home to the destination of the current trip:

$$r(t) = \texttt{GISdistJourneyStartP}(t).$$

It fluctuates over the day as geographic reach expands and contracts, directly tracing the dynamic footprint of presence in space. Radial distance is an observed state variable, not a latent intention—it shows where people *are*, not where they plan to be. This is the central variable used in the continuity-based analysis.

For validation and consistency checks, we also compute the *cumulative distance* $d(t)$, representing total mobility effort up to time t:

$$d(t) = \sum_{t_i \le t} \texttt{GISdist}_i.$$

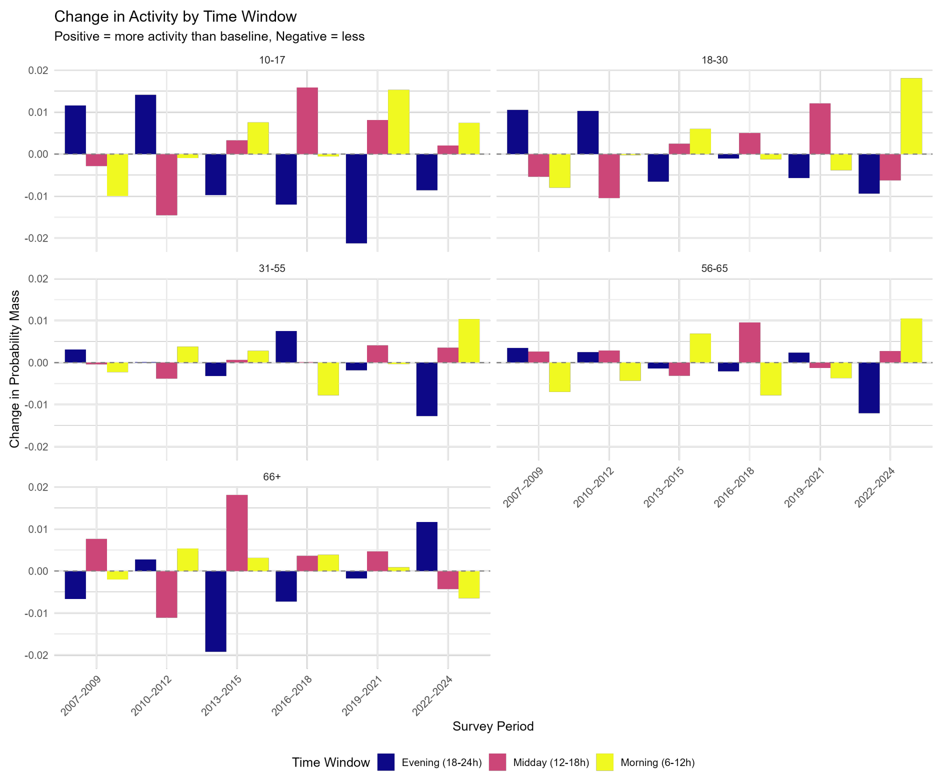
It increases monotonically over the day and provides a benchmark for interpreting $r(t)$. While not directly used in the continuity framework, $d(t)$ offers a complementary perspective on daily travel effort and helps ensure internal coherence of the dataset.

As shown in Table 3, $d(t)$ increases monotonically, while $r(t)$ expands and contracts over the day. Person-days with no travel ($d(t) = r(t) = 0$ for all t) are included without special treatment, contributing density mass near $(r, d) = (0, 0)$ and thus capturing systematic differences in inactivity across cohorts and periods.

Supplementary Table 3. Illustrative example of cumulative and radial distances for a stylized person-day. The final column tracks the fraction of the day spent away from home.

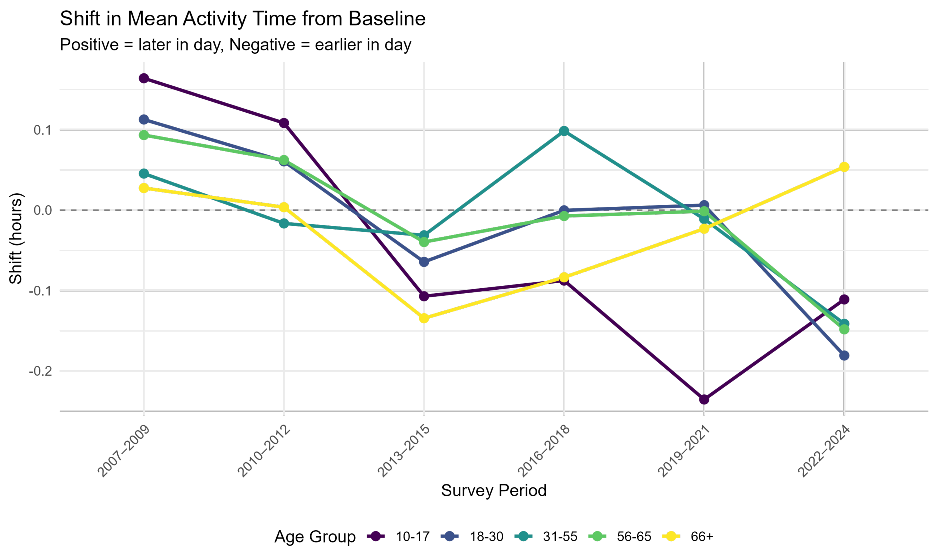
Time (min)	**Trip Purpose**	**Radial** $r(t)$ **[km]**	**Cumul.** $d(t)$ **[km]**	**Time away** [%]
0–840	At Home	0.0	0.0	0.0
840	Home → Leisure	14.7	0.0	0.0
855	Stay (Leisure)	14.7	14.7	1.0
900	Leisure → Leisure	14.4	16.9	4.2
903	Stay (Leisure)	14.4	16.9	4.4
1020	Leisure → Leisure	14.7	19.0	12.5
1023	Stay (Leisure)	14.7	19.0	12.7
1050	Leisure → Home	0.0	33.7	14.6
1065–1440	At Home	0.0	33.7	14.6

Supplementary Figure 1: Shift in temporal activity windows when away from home across cohorts and years (related to Fig. 4 in the main text).



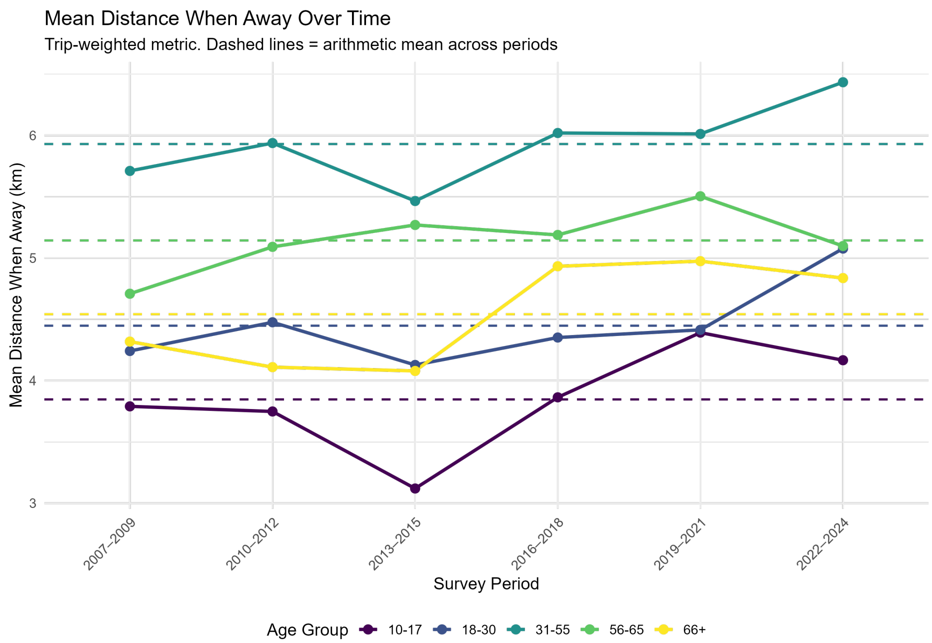
Supplementary Figure 1. Changes in temporal activity distribution when away from home across discrete time windows by age cohort and survey period. Bars represent the change in probability mass (relative to baseline) within three time windows: morning (6–12h, yellow), midday (12–18h, pink), and evening (18–24h, blue). Positive values indicate increased activity relative to baseline, negative values indicate decreased activity. Younger cohorts (10–30 years) show modest increases in morning activity and decreases in evening activity, suggesting slight temporal compression toward daytime hours. The oldest cohort (66+) displays more variable shifts across periods, while middle-age cohorts (31–65 years) show minimal systematic changes. These discrete window analyses complement the continuous temporal profile analysis in Fig. 4 of the main text, confirming that temporal shifts remain small in magnitude across all demographic groups.

Supplementary Figure 2: Mean time shift across cohorts and periods (related to Fig. 4 in the main text).



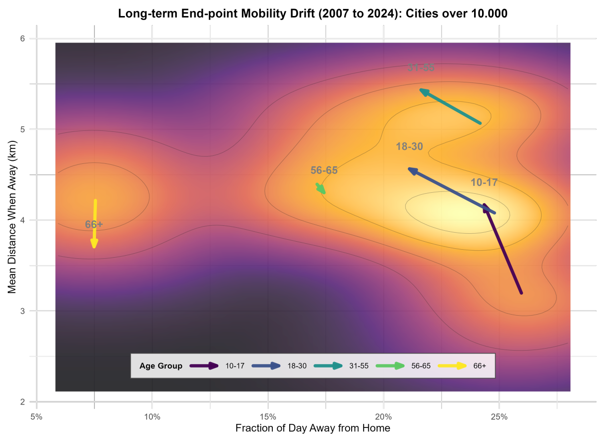
Supplementary Figure 2. Deviation in mean timing of daily away-from-home activity across cohorts and survey periods. Each point represents the shift (in hours) of the probability-weighted mean activity time relative to each cohort's pooled 2007–2024 baseline, computed treating time of day as a circular variable over the 24-hour cycle. Positive values indicate later average activity timing, negative values indicate earlier timing. All cohorts exhibit shifts within ±0.25 hours (±15 minutes), with no consistent directional trends across the 17-year observation window. The minimal drift confirms that the central tendency of daily temporal patterns remains remarkably stable despite period-specific fluctuations, complementing the temporal stability shown in Fig. 4.

Supplementary Figure 3: Mean distance when away from home across periods and cohorts (related to Fig. 5 in the main text).

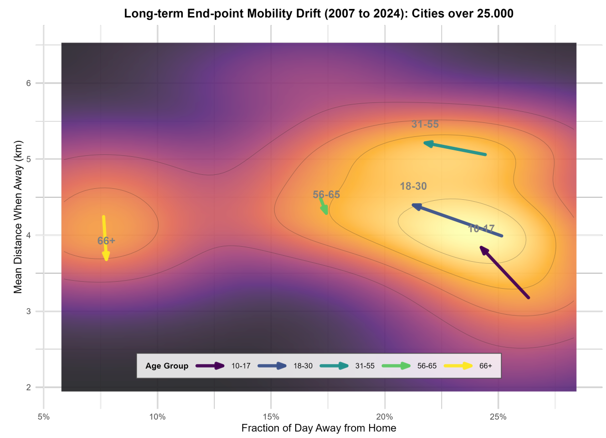


Supplementary Figure 3. Evolution of mean distance from home when away, by survey period and age cohort. Values are trip-weighted, reflecting the typical distance experienced during out-of-home trips rather than time-weighted exposure. Dashed horizontal lines indicate each cohort's arithmetic mean across all six survey periods. Younger cohorts (10–30 years) show the largest increases, with 2022–2024 values exceeding their period-averaged baselines, while older cohorts (56+ years) remain relatively stable around their respective baselines. These absolute distance trajectories complement the percentage-change heatmap in Fig. 5, confirming that when younger people leave home, they travel systematically farther than in earlier periods.

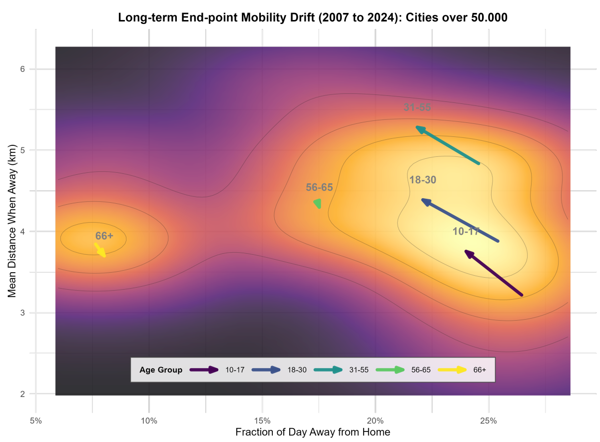
Supplementary Figure 4: Endpoint drift across urban scales (related to Fig. 6a in the main text).



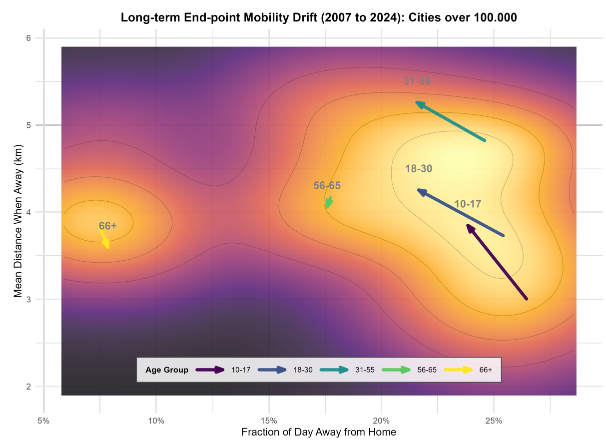
(a) Cities > 10,000



(b) Cities > 25,000



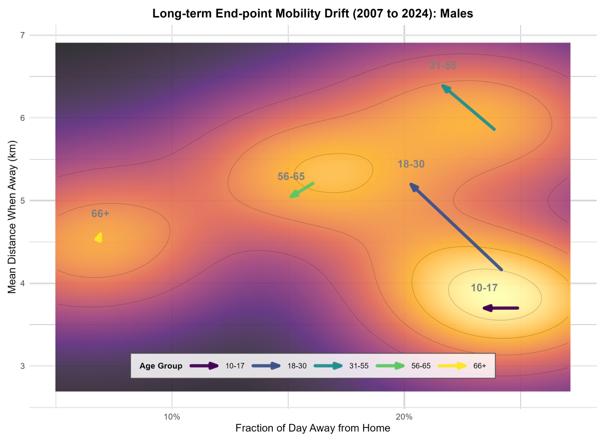
(c) Cities > 50,000



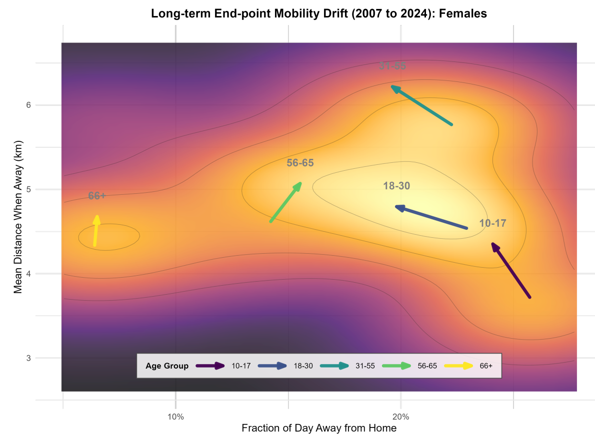
(d) Cities > 100,000

Supplementary Figure 4. **Endpoint mobility drift across urban scales.** All panels restrict analysis to respondents residing in cities with at least 10,000 inhabitants, with panels (b–d) applying additional minimum thresholds as indicated. Drift vectors represent direct displacement from baseline (2007–09) to final period (2022–24). The remarkable consistency of drift patterns across urban scales demonstrates that action-space geometry is fundamentally independent of city size: younger cohorts (10–30 years) show consistent spatial expansion and temporal contraction regardless of urban context, while older cohorts remain stable. It is also worth noting that these drift vectors are somewhat longer than the baseline drift vector (Fig. 6a, in the main text). This is because here we restrict to cities above 10,000 inhabitants, while the baseline vector includes all respondents including those in rural areas. This suggests that drift patterns are more pronounced among urban residents.

Supplementary Figure 5: Endpoint mobility drift by sex (related to Fig. 6a in the main text).



(a) Males



(b) Females

Supplementary Figure 5. **Endpoint mobility drift by sex.** Drift vectors represent direct displacement from baseline (2007–09) to final period (2022–24) for males (a) and females (b). While middle-age cohorts (31–65 years) exhibit similar drift patterns across sexes, notable differences emerge in younger cohorts: adolescent males (10–17) show pure temporal contraction while adolescent females show spatial and temporal expansion, and young adult males (18–30) demonstrate stronger spatial expansion than their female counterparts. Despite these sex-specific differences in drift magnitude and direction for younger ages, the fundamental age-stratification pattern persists across both sexes, with mobility changes concentrated in younger cohorts while older groups remain relatively stable.

Supplementary Table 4: Path complexity analysis

Supplementary Table 4. **Path complexity metrics for cohort trajectories (2007–2024).** Tortuosity measures the ratio of actual path length to straight-line displacement; values near 1.0 indicate direct movement while higher values reflect meandering or period-specific fluctuations. The mean resultant length (R) quantifies directional consistency, with values near 1.0 indicating all period-to-period transitions point in similar directions. Circular standard deviation provides an intuitive measure of angular spread.

Age Group	**Displacement** (km)	**Path Length** (km)	**Tortuosity** (ratio)	**R**	**Circular SD** (degrees)
10-17	0.479	2.187	4.57	0.200	102.9
18-30	0.750	1.453	1.94	0.586	59.2
31-55	0.536	1.532	2.86	0.408	76.7
56-65	0.162	1.141	7.06	0.216	100.3
66+	0.328	1.463	4.46	0.205	101.9

Displacement: Straight-line distance from baseline (2007–09) to final period (2022–24).
Path Length: Total distance traveled through action-space across all period-to-period transitions.
Tortuosity: Path length / displacement. Values of 1.0 indicate perfectly straight trajectories; higher values indicate deviation from direct movement.
R (Mean Resultant Length): Circular statistic measuring directional consistency (range: 0–1). Higher values indicate period-to-period vectors point in more similar directions.
Circular SD: Angular dispersion of trajectory directions in degrees. Lower values indicate tighter angular clustering.

Methodological Note: Radial Distance Proxy and Action-Space Estimation

Our kernel density estimation yields conservative estimates of time away from home, capturing 70–85% of the values reported in descriptive statistics (Table 1), depending on age group. Similarly, mean radial distances when away (4–6 km) are substantially lower than accumulated daily travel distances (16–33 km). This reflects both the nature of radial measurement and our proxy-based estimation approach.

Measurement Approach and Necessary Approximations The Danish National Travel Survey does not provide destination coordinates due to GDPR protections, nor does it continuously track whereabouts during travel. To construct continuous time-space trajectories, we must therefore choose a proxy location for activity episodes. We use trip departure locations (`GISdistJourneyStartP`) as proxies for radial distance during subsequent activities. The alternative—using arrival locations—would introduce similar approximations with comparable biases.

This approach systematically underestimates both time away and radial distances because it assumes individuals remain at approximately the same radial distance as their departure point during activities, whereas actual destinations may be further or closer to home. Additionally, our radial distance metric measures crow-flight distance from home at each time step, which differs fundamentally from accumulated travel distance. A round trip of 30 km (15 km each way) yields a maximum radial distance of 15 km and a time-weighted mean radial distance substantially lower than 30 km.

Validity of Comparative Analysis This systematic underestimation does not affect our conclusions because the measurement approach is consistent across all age groups, time periods, and activity types. Our analysis focuses on *relative changes* in action-space geometry rather than absolute magnitudes. The kernel density difference distributions, drift fields, and divergence calculations compare cohorts under identical measurement conditions, meaning systematic biases cancel out in relative comparisons.

Critically, the choice between using departure versus arrival locations affects absolute positioning in (d, t) space but not relative patterns: whichever proxy we select would apply uniformly to all observations, preserving the validity of cross-cohort and temporal comparisons. The topology of action-space evolution—the relative positioning of cohorts and the direction of temporal shifts—remains valid even as absolute scales are conservatively estimated.

Alternative Approaches and Trade-offs Correcting this bias would require destination coordinates for each activity, which necessitate either GPS tracking data (unavailable for this historical period), detailed address-level destination coding (prohibitively expensive at national scale), or imputation based on trip purpose and land-use data (introducing different assumptions and biases). Given that our research questions concern relative patterns and temporal dynamics rather than absolute magnitudes, the proxy-based approach provides valid measurements for our continuity-based analysis while maintaining respondent privacy. The consistent application of this approach across all measurements ensures that our findings regarding action-space evolution remain robust.