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Detour-based metrics of alcohol availability along walking commutes

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Abstract. As evidence accumulates that even moderate alcohol use carries health risks, policy interest is shifting toward reducing everyday exposure; yet existing spatial metrics still mostly map outlet presence rather than behaviorally plausible purchase opportunities along routine trips. We introduce behaviorally informed, detour-based indices tailored to after-work alcohol acquisitions on walking commutes. Using preference surveys of adults in two German cities, we infer empirical "detour budgets" for after-work alcohol runs and embed them in a home-level index capturing the share of transit–home walking paths that include at least one feasible purchase opportunity, and a store-level leverage index capturing how many such paths each outlet can intercept. Under a 250 m detour budget, roughly the extra distance that half of respondents are willing to walk, half of stop–home walking segments and 29% of homes are exposed on all routes. Kiosks, while only about 28% of outlets, account for roughly 35% of this after-work leverage. Applying the indices to European alcohol-policy regimes, we show that a state retail monopoly cuts mean home exposure by about 75%, while targeted removal of the 25% most exposure-imposing outlets achieves almost the same reduction as a selective licensing pattern that shuts more stores. These findings show how behaviorally informed exposure metrics can support more targeted alcohol-availability policy and be extended to other purchase-chain-specific exposures.

Submission Type. model; analysis; case study.

BoK Concepts. [AM] Analytical Methods; [GC] Geocomputation; [TA] Thematic and application domains

Keywords. alcohol availability; exposure metrics; walking commutes; revealed preference; stated preference; alcohol policy

1 Introduction

Recent Global Burden of Disease analyses report no significant mortality benefit for moderate drinkers compared with lifetime abstainers and show that alcohol causally increases the risk of at least seven cancers (U.S. Surgeon General, 2025). Risk increments are detectable at around one drink per day and rise monotonically at higher intake levels. These findings are shifting policy attention away from heavy drinking toward reducing population-level exposure, including among otherwise healthy adults whose consumption falls within current guideline ranges.

A well-known policy lever is to restrict alcohol sales spatially and temporally (Bäuml et al., 2023). For this to be effective, the restriction must align with where and when people obtain alcohol. Not all purchasing behaviors are equally sensitive to changes in convenience. Large "stock-up" or weekend bulk purchases are typically planned, bundled with other grocery shopping, and often undertaken by car, enabling consumers to compensate for local restrictions by traveling farther, switching stores, or rescheduling trips (Reutterer & Teller, 2009). In contrast, a non-trivial share of weekday home-based drinking occasions occurs in the evening and is associated with relaxing after work. As such, alcohol is often purchased on the same day, typically on or near the route home from work. These purchases are tightly constrained by daily routines, concentrating exposure along specific times and routes (Room et al., 2012). Yet existing path- and activity-space exposure measures typically use generic path segments or buffers and do not distinguish behaviorally plausible purchase opportunities from merely co-located outlets (Freisthler et al., 2021).

In this paper, we develop a behaviorally informed, detour-based index of alcohol exposure tailored to same-day after-work purchases. Using survey data from adults in Mannheim and Heidelberg, Germany, we estimate empirically grounded 'detour budgets'—the additional distance individuals are willing to travel to buy alcohol—and then apply these constraints in a Mannheim case study of path-based exposure. These metrics uncover how alternative retail regimes would change the opportunity structures of after-work alcohol purchase. We demonstrate this by applying the index to stylized retail regimes: a 'Nordic' monopoly in which a limited number of outlets operate (Norström et al., 2010), an 'English' selective licensing system (Home Office, 2024), and permissive systems (Berdzuli et al., 2020).

The remainder of the paper presents the survey-based empirical calibration and exposure metrics, then reports the empirical and policy-simulation results, and finally discusses implications and limitations.

2 Methods

This section summarizes the empirical calibration of detour budgets and the construction of the home-level exposure and store-level leverage indices used in the policy analysis.

We model after-work alcohol purchasing as detours from direct homebound walks on a pedestrian network, where alcohol outlets are defined as off-premise retail points. Let O denote the origin of the homeward leg (workplace or transit stop), D the destination (home or transit stop, and M an alcohol outlet. For any triple (O, M, D) we define the direct path length $d(O, D)$, the path with a stop $d(O, M) + d(M, D)$, and the detour distance

$$\Delta(O, M, D) = d(O, M) + d(M, D) - d(O, D) \geq 0, \quad (1)$$

where all distances are measured as network shortest paths. For a given homeward trip, any outlet with $\Delta(O, M, D) \leq w$ is treated as a feasible same-day purchase opportunity, where w is a detour budget.

The survey captured homebound trips in which alcohol was purchased to empirically calibrate the detour budgets w. In the exposure analysis, we focused on walking trips from transit stops to homes after work as a policy example. For each residential building we enumerate stop–home routes from nearby stops, label routes as exposed for a given w if at least one outlet is reachable within the additional distance, and aggregate these indicators into a home-level exposure index and a store-level leverage index that attributes exposure to outlets according to the number of homeward routes they intercept.

2.1 Online survey

We performed an online, map based revealed- and stated-preference survey in Mannheim and Heidelberg, two mid-sized cities in southwestern Germany with substantial walking/public transit commuting. Alcohol is widely available in supermarkets, kiosks, petrol-station shops, and liquor stores, without restrictions on sales hours or locations (Berdzuli et al., 2020). The survey took place between September and Decepmber 2025 among adults (18-64) in work or education, who had, in the past 3 months, had included a walking segment on the way home from such a place and bought alcoholic drinks in a shop on the way. Eligible respondents were adults aged 18–64 who were in work or education/training and reported at least one such trip in the past 3 months; participants were recruited via QR-code flyers distributed at a university campus, a central bar, and the Mannheim Christmas market. All participants provided informed consent before beginning the survey.

In the revealed-preference module, respondents mapped one such trip as a three-point sequence (O_i, M_i, D_i) on an interactive web map. They marked the origin of the homeward leg, the shop where alcohol was bought, and the destination. We then snapped these points to a pedestrian network $G = (V, E)$ built from OpenStreetMap using the Python package OSMnx (Boeing, 2017), the corresponding network shortest-path distances between (O_i, M_i, D_i). For each trip i we obtained the distances

$$d_{OM,i} = d(O_i, M_i), d_{MD,i} = d(M_i, D_i), d_{OD,i} = d(O_i, D_i),$$

the travelled distance with a purchase

$$L_i^{with} = d_{OM,i} + d_{MD,i}, \quad (2)$$

and the detour (Figure 1)

$$\Delta_i = L_i^{with} - d_{OD,i} \quad (3)$$

We summarized the empirical distribution of Δ_i and regressed it on $d_{OD,i}$,

$$\Delta_i = \alpha + \beta d_{OD,i} + \varepsilon_i, \quad (4)$$

to test whether detour length depends on baseline path length.

In the stated-preference module, respondents considered the same underlying homeward origin–destination pair (O_i, D_i) and, in four yes/no choice tasks, chose between going straight home and making an additional detour of $X \in \{1, 3, 5, 7\}$ minutes to buy alcohol. Each task asked them to choose between going directly home and making the additional detour to buy alcohol before continuing home.

We then estimated a panel binary logit model, where y_{it} denotes choosing the detour in task t (1=yes, 0=no), $ExtraTime_{it}$ the additional minutes, T_i the usual homebound walk time, and $T_i^c = T_i - T^*$ the centered baseline time around the sample median T^*.

$$U_{it}^{detour} = \alpha + \beta ExtraTime_{it} + \gamma(ExtraTime_{it} \times T_i^c) + \varepsilon_{it}, \quad (5)$$

with the utility of "go straight home" normalized to zero. For three reference acceptance probabilities $p^* \in \{0.75, 0.50, 0.25\}$ at a baseline walk T^*, we solved

$$Pr\,(y_{it} = 1 \mid ExtraTime = \hat{w},\, T_i = T^*) = p^*, \quad (6)$$

treated these solutions $\hat{w}(p^*, T^*)$ (minutes) as time-based detour budgets, and converted them to distances (≈4.7 km/h). We then compared them with the revealed quantities of Δ_i, and selected three corridor widths $w \in \{100, 250, 400\}$ that, as explained in the Results section, we deemed conservative, typical, and liberal tolerances. These thresholds are then applied uniformly across Mannheim as empirically calibrated exposure cutoffs, not as individualized predictions for each stop–home pair.

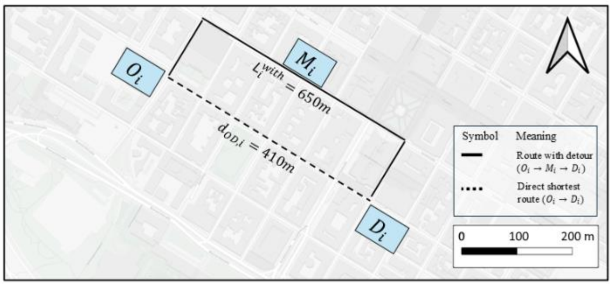

Figure 1. Conceptual example of an after-work detour trip.

2.2 Homebound exposure indices

Our indices are implemented on the pedestrian network of Mannheim with features extracted from OpenStreetMap. For each residential building $d \in \mathrm{D}$ we identified all transit stops $o \in \mathrm{O}$ whose network shortest path to d was ≤ 500 m; let O_d be this set, consistent with a standard short walk-to-transit threshold. For each path $o \to d$ and detour budget $w \in \{100, 250, 400\}$, we tested every outlet $m \in M$ and labelled the path exposed if at least one outlet satisfies

$$\Delta_{(o,m,d)} = d(o,m) + d(m,d) - d(o,d) \leq w. \quad (7)$$

The binary indicator

$$R_{od}(w) = \begin{cases} 1, if\ at\ least\ one\ outlet\ m \in M\ satisfies\ \Delta_{(o,m,d)} \leq w, \\ 0, otherwise. \end{cases} \quad (8)$$

flags exposed paths. For each destination d, the home-level exposure index (Figure 2) is

$$E_d(w) = \frac{1}{|O_d|} \sum_{o \in O_d} R_{od}(w). \quad (9)$$

We aggregated $E_d(w)$ over a regular hexagonal grid. Let D_g be the homes whose centroids fall in cell g. Each home d received a capacity weight $c_d = a_d f_d$ (footprint area times the number of floors), and the grid-cell exposure index is

$$E_g(w) = \frac{\Sigma_{d \in D_g} E_d(w) c_d}{\Sigma_{d \in D_g} c_d}. \quad (10)$$

We also computed a static outlet density

$$S_g = \frac{|M_g|}{A_g}, \quad (11)$$

and a store-level average index. Let N_d denote the number of stop-home paths associated with destination d, and n_{md} the number of those paths that pass outlet m within w. The leverage of outlet m (Figure 3) is

$$L_m = \sum_{d \in \mathrm{D}} c_d \frac{n_{md}}{N_d} \quad (12)$$

representing the capacity-weighted share of homeward routes that would pass near store m under the moderate detour tolerance. The area-level leverage is obtained by summing over outlets in each cell,

$$L_{mg} = \sum_{m \in \mathrm{M}_g} L_m. \quad (13)$$

2.3 Policy analysis

We assessed regulatory configurations by recomputing exposure relative to the baseline Mannheim configuration, in which all off-premise outlet types considered here—supermarkets, kiosks, petrol-station shops, and specialist alcohol stores—are retained. We then considered three alternatives: (i) targeted licensing that removes the 25% of outlets with the highest L_m; (ii) a Nordic monopoly retaining only liquor/wine outlets; and (iii) an English/Welsh selective licensing regime retaining supermarkets and liquor/wine outlets but removing kiosks and petrol shops.

2.4 Data and software availability

All code used to construct the network, compute indices, and run policy simulations is publicly available at https://github.com/Nirfff/Alcohol. The underlying spatial data are derived from OpenStreetMap and can be recreated from the raw OSM database using the scripts and configuration files in the repository. The individual-level survey data contain sensitive location information and cannot be shared openly.

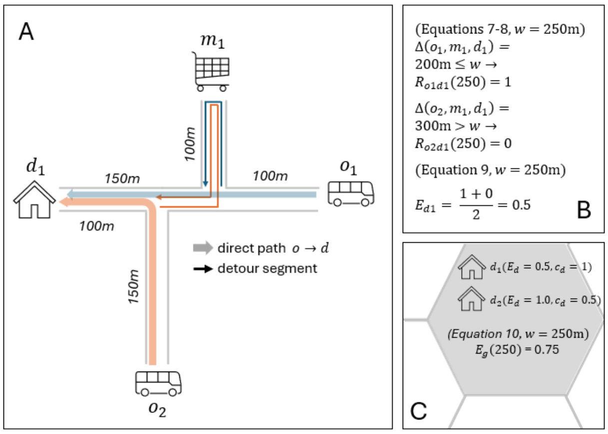

Figure 2. Homeward exposure metrics. (A) two routes from transit stops to a dwelling, showing the direct route and a detour to an alcohol outlet; (B) homebound exposure metric calculation; (C) aggregation into an area-level exposure index, assuming an additional dwelling.

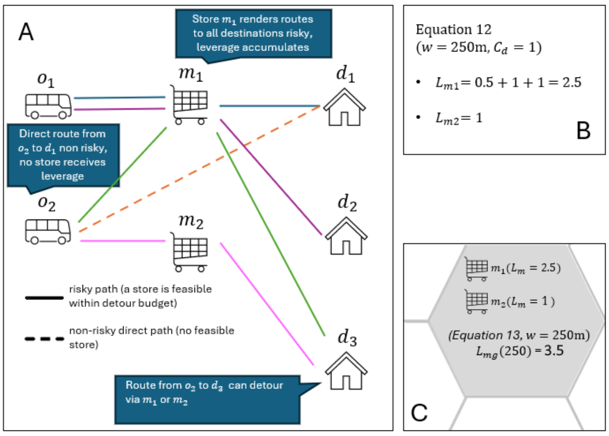

Figure 3. Illustration of store-level leverage. (A) schematic example of stop–home routes linking two transit origins, two alcohol outlets, and three residential destinations; (B) example store-level leverage values for the two outlets; and (C) aggregation of store-level leverage into an area-level outlet leverage index.

3 Results

We first report the revealed- and stated-preference detour estimates and then show how the resulting budgets shape home exposure, store leverage, and policy-simulation outcomes.

3.1 Preference detours

Of 207 eligible respondents, 195 completed both the revealed- and stated-preference modules and were retained for analysis (Table 1). Respondents included 95 residents of Mannheim, 71 of Heidelberg, and the remainder from nearby municipalities. The revealed-preference detour distribution had 25th, 50th, and 75th percentiles of approximately 32 m, 107 m, and 267 m, with about 90% of trips at or below 400 m (Figure 4). A regression of Δ_i on the direct origin-destination distance $d_{OD,i}$ (Equation 4) yielded a small negative slope (β ~ -0.052, R^2 = 0.02), indicating that detour size is only weakly related to baseline path length.

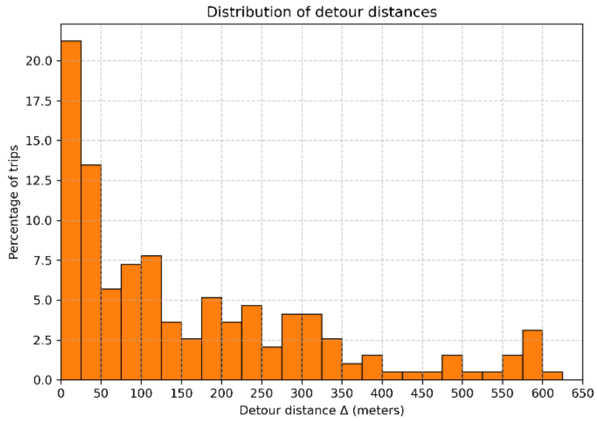

Figure 4. Empirical distribution of detour distances (Δ_i), computed from observed alcohol-purchase trips (n = 195).

The stated-preference module generated 780 binary choices. Acceptance declined monotonically with additional walking time, from about three quarters at 1 minute to about one fifth at 7 minutes. In the logit model (Table 2), extra walking time strongly reduced the odds of choosing a detour, while longer baseline walks had a smaller additional effect. Evaluated at the median baseline walk T^* and three reference acceptable probabilities $p^* \in \{0.75, 0.50, 0.25\}$, the implied time budgets were approximately 1.4, 4.2 and 7.0 minutes, corresponding to distance-based budgets of roughly 107, 327, and 546 m. Taking the stated-preference budgets (107, 327, and 546 m) as the primary guide, but rounding them downward toward the revealed-preference distribution (32, 107, and 267 m), we use $w \in \{100, 250, 400\}$ m as practical conservative, intermediate and liberal detour budgets for the spatial analysis.

Table 1. Summary of route characteristics and detour metrics by trip context and store type.

Category	Subgroup	n	Share of trips (%)	Mean direct path $d_{OD,i}$ (m)	Median direct path $d_{OD,i}$ (m)	Mean detour Δ_i (m)	Median detour Δ_i (m)
Trip context	Transit→Home	84	43.1	443	447	205	175
	Work→Home	78	40.0	1,275	1,250	142	91
	Work→Transit	33	16.9	427	467	125	67
Store type	Kiosk	62	31.8	-	-	135	72
	Liquor/wine	18	9.2	-	-	146	101
	Petrol shop	15	7.7	-	-	196	164
	Supermarket	100	51.3	-	-	186	138
Overall	All trips	195	100.0	773	543	167	107

Table 2: Panel logit estimates for stated-preference detour choice

Term	Coef.	SE	p-value
Intercept (α)	1.64	0.19	< 0.001
$ExtraTime_{it}$, minutes (β)	−0.391	0.034	< 0.001
$ExtraTime_{it} \times T_i^c(\gamma)$	−0.0205	0.006	< 0.001
Respondents: 195; Observations: 780; Pseudo-R^2: 0.17			

3.2 Homebound exposure and store leverage

The Mannheim network comprised several hundred transit stops, 366 alcohol outlets and roughly 27,000 residential buildings after snapping to the walking network (Table 3). Homes with at least one transit stop within 500 m network distance generated a large set of feasible stop-home paths, of which 32%, 49% and 62% were classified as exposed at $w \in \{100, 250, 400\}$ m respectively. Under the intermediate detour budget w = 250 m, we observed a median of two reachable outlets per exposed route. The composition of outlets intersecting exposed corridors broadly matched Mannheim's outlet mix but kiosks were clearly over-represented at the narrowest detour, converging toward the city baseline at wider w (Table 4).

Table 3. Counts of origin, midpoint, and destination features in the Mannheim network dataset.

Feature	Category	Count
Origins (O)	-----	675
Midpoints (M)	Supermarket	171
	Kiosk	103
	Petrol shop	50
	Alcohol store	42
	Total	366
Destinations (D)	-----	26,955

Table 4. Store-type composition of exposed corridor intersections vs. citywide outlet mix

Store type	Citywide outlets (%)	w = 100 m (%)	w = 250 m (%)	w = 400 m (%)
Supermarket	46.7	41.6	44.2	45.4
Kiosk	28.1	39.8	35.2	33.5
Petrol shop	13.7	11.2	11.6	11.7
Alcohol store	11.5	7.5	9.0	9.4

Figure 5 shows the cumulative distribution of home-level exposure $E_d(w)$. At w = 100 m about half of homes had no exposed stop-home routes, at w = 250 m the distribution was roughly one-third unexposed, one-third partially exposed and one-third fully exposed, and at w = 400 m, full exposure became dominant with only about 30% of homes remaining unexposed. Thus, under the intermediate budget, roughly one third of homes are insulated from after-work walking exposure, one third see some routes intersect outlets and one third face unavoidable exposure on all mapped routes.

Hex-level exposure maps $E_g(w)$ (Figure 6a-c) reveal a structured spatial pattern: high values concentrate in central mixed-use districts and selected transit nodes and spread along spines and connecting corridors as w increases. The mobility-based exposure index $E_g(250\ m)$ and static outlet density S_g (Figure 6d) are only moderately aligned (Spearman p = 0.61, Pearson r = 0.5), indicating that density and path-based exposure capture related but distinct aspects of availability.

Store leverage L_m at w = 250 m was right-skewed. Supermarkets contributed the largest share of total leverage, but kiosks exhibited the highest typical leverage and accounted for just over one third of leverage despite being fewer in number, reflecting their siting directly on common walking approaches between spots and housing. Aggregated to hexagons, only 12.1% of cells had any leverage, and the top 5% of cells captured 88.2% of the total (Figure 7), pointing to a small number of locations that dominate potential after-work purchasing opportunities along walking commutes.

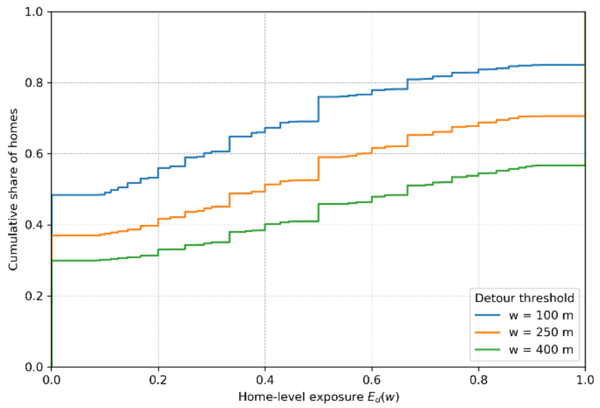

Figure 5: Cumulative distribution of home-level exposure to alcohol outlets across detour thresholds $w \in \{100,250,400\}$. Because each home is connected to only a handful of transit stops, $E_d(w)$ can take only a small set of rational values, producing the stepwise appearance of the empirical distribution.

3.3 Policy simulations

Policy simulations at w = 250 m (Table 5, Figure 8) showed substantial reductions in path-based exposure under all three scenarios relative to the baseline mean = 0.40 and median = 0.33. Targeted removal of the top 25% of outlets by leverage L_m retained 274 of 366 stores and reduced mean E_g to 0.30 and the median to 0.15. The English-style licensing regime, which kept 213 supermarkets and liquor stores and removed kiosks and petrol shops, produced similar aggregate reductions with mean = 0.29 and median = 0.11. The Nordic monopoly scenario, retaining only specialist liquor stores, lowered mean and median E_g to near zero in most hexagons. Spatial difference maps (Figure 8) show that targeted removal mainly trims high-exposure peaks around key transit nodes and peripheral single-outlet catchments, the Nordic regime almost eliminates exposure except for short chains around the remaining liquor stores, and the English-style regime concentrates reductions along the main commuting spine and selected neighborhood centers where kiosks cluster.

4 Discussion

This study sits at the intersection of urban planning, behavioral science, public health, and transport geography. Across these perspectives, its central contribution is policy-relevant: a behaviorally informed exposure metric that identifies where after-work purchase opportunities are embedded in routine walking paths and how different retail regimes reshape them.

In walkable, mixed-use cities, the same spatial logic that brings everyday essentials within easy reach also places alcohol and other impulse goods directly along routine travel paths. Our analysis shows that when after-work walking is common, even a small number of strategically located outlets can shape much of this exposure, making it a matter not of overall availability, but of whether opportunity lies just off-route or directly in one's way. From an exposure-assessment perspective, our approach reflects a broader shift toward behaviorally meaningful metrics that go beyond residential proximity to capture how environments intersect with specific routines. By mapping after-work walking routes against empirically plausible detours, we show how exposure can be defined not by static co-location, but by the spatial and temporal contours of real-world behavior.

From the perspective of behavioral archetypes, our focus on after-work, transit-linked alcohol purchases offers a policy-relevant exposure pattern grounded in real-world routines and supported by everyday narratives of attraction. While this lens is necessarily narrow and based on a localized sample, it illustrates how formal metrics can be built from lived experience, and points to the need for broader mapping of other common exposure pathways. From an alcohol-policy design perspective, our work speaks to how different regulatory models shape everyday exposure not just through availability in the abstract, but through the placement of outlets relative to routine behaviors. By showing how a small number of strategically located shops can embed alcohol into daily walking routes, our findings highlight the spatial leverage available even within relatively permissive retail regimes.

From a systems perspective, the diversity of alcohol retail regimes offers a natural experiment in how societies shape everyday opportunity structures, yet policymaking still relies on crude tools that miss behaviorally salient patterns. Our findings show that it is possible to build targeted, behavior-linked exposure metrics using accessible data, laying the groundwork for more precise, path-oriented policy design that moves beyond outlet counts toward identifying which outlets matter most, for whom, and in what contexts.

Several limitations of our study follow directly from its ambition to link specific behaviors, paths, and policy levers. First, our empirical calibration relies on a small convenience sample from Mannheim/Heidelberg, recruited at high-footfall sites and skewed toward younger adults, so it is intended for local calibration rather than broad generalization. Second, our policy scenarios are stylized abstractions that simplify complex licensing systems and regulatory contexts. Third, our spatial exposure metrics rest on imperfect map data and assume uniform demand across homes and routes. Fourth, we implemented fixed detour budgets and focused only on transit-to-home walking, omitting other modes and influences on detour behavior. Extending the same logic to other trip types and exposures is a natural next step.

4 Conclusion

We introduced a behaviorally informed, detour-based metric of alcohol availability along walking commutes and showed that it captures exposure patterns that static outlet density misses. In Mannheim, a moderate detour budget already makes many homebound routes and homes exposed, with certain outlet types exerting disproportionate leverage. The policy simulations further show that the metric can distinguish not only how much exposure is reduced, but which regulatory configurations drive that reduction. More broadly, the approach offers a template for linking spatial exposure measurement to concrete policy design.

Declaration of Generative AI in writing

The authors used generative AI tools for language editing and polishing; all analysis and interpretations are the authors' own.

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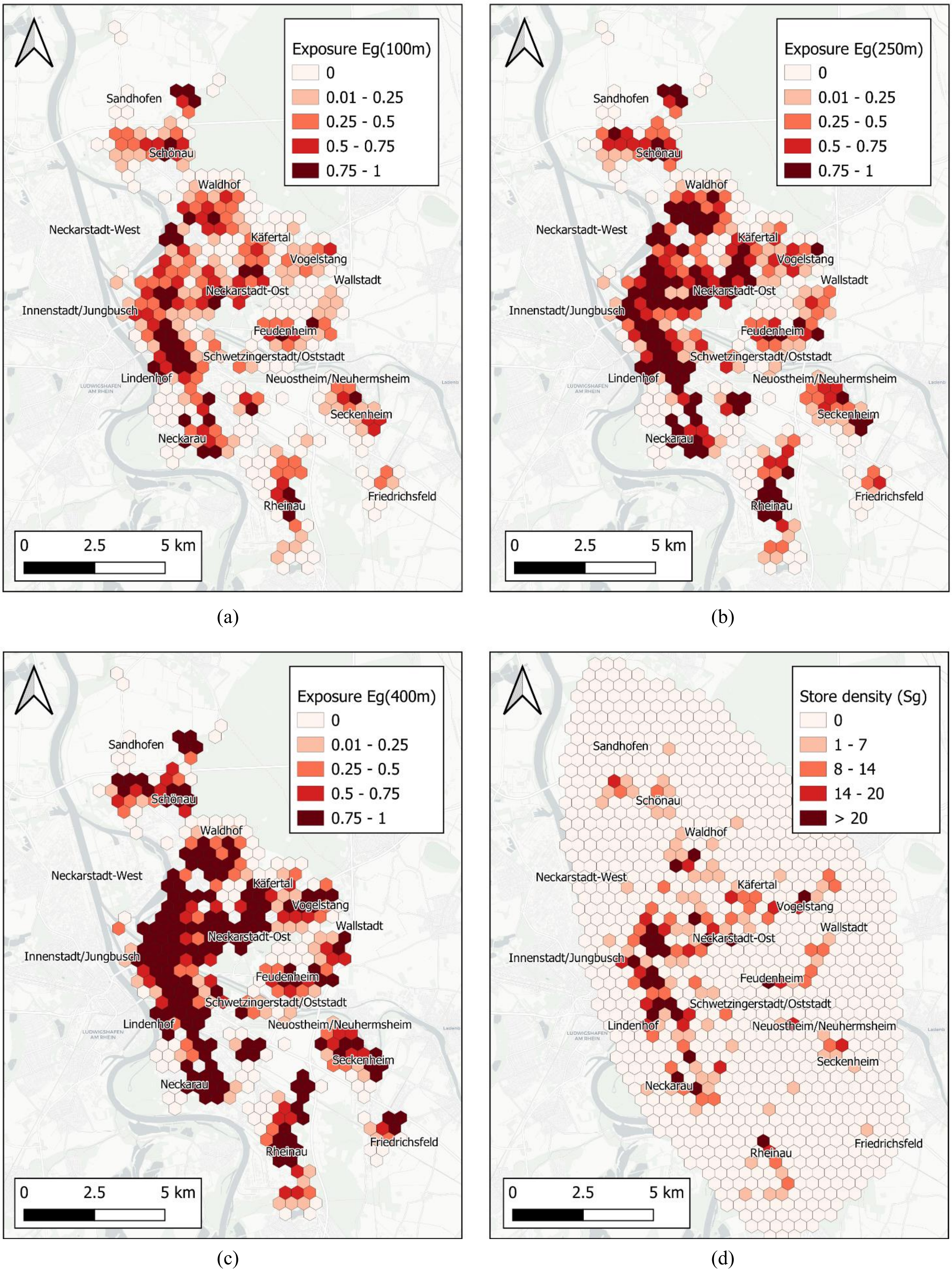
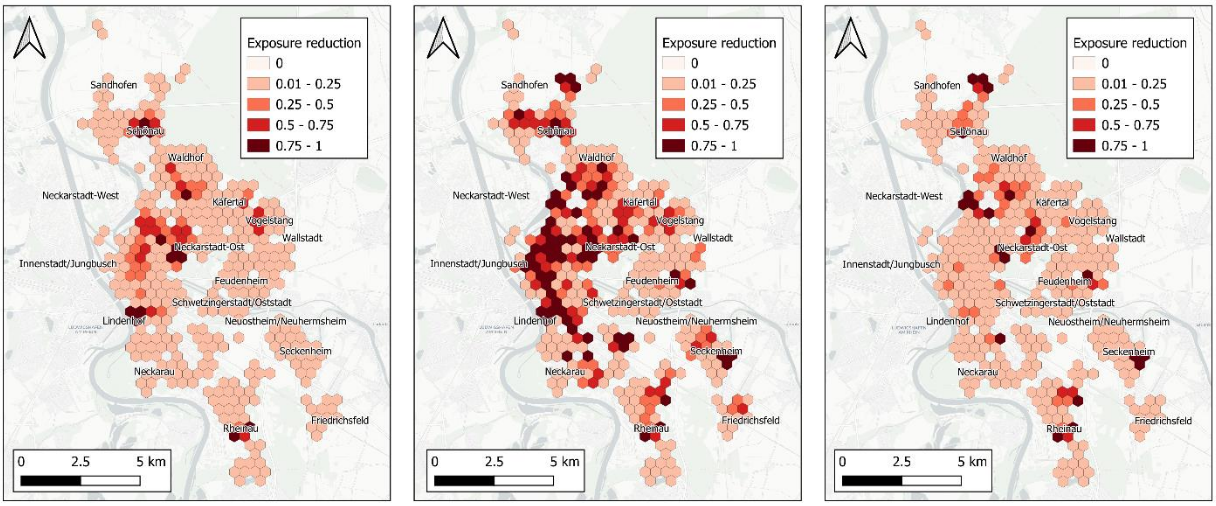


Figure 6: Hex-level path-based exposure E_g for detour thresholds $w \in$ { (a) 100 , (b) 250 , (c) 400 } and (d) outlet density S_g.

Table 5: Summary of policy scenario outcomes at $w = 250m$.

Scenario	**Stores kept**	**Mean exposure $E_g(250\,m)$**	**Median exposure $E_g(250\,m)$**	**Mean change ΔE_g**	**Median change ΔE_g**
Top-25%	274	0.30	0.15	–0.10	–0.18
Nordic	42	0.09	0.00	–0.31	–0.33
English	213	0.29	0.11	–0.11	–0.22



(a) (b) (c)

Figure 8: Change in hex-level exposure $E_g(250\ m)$ relative to baseline under three policy scenarios: (a) targeted removal of the top 25% of outlets by leverage, (b) Nordic monopoly (liquor stores only), and (c) English-style selective licensing (supermarkets and liquor stores only).

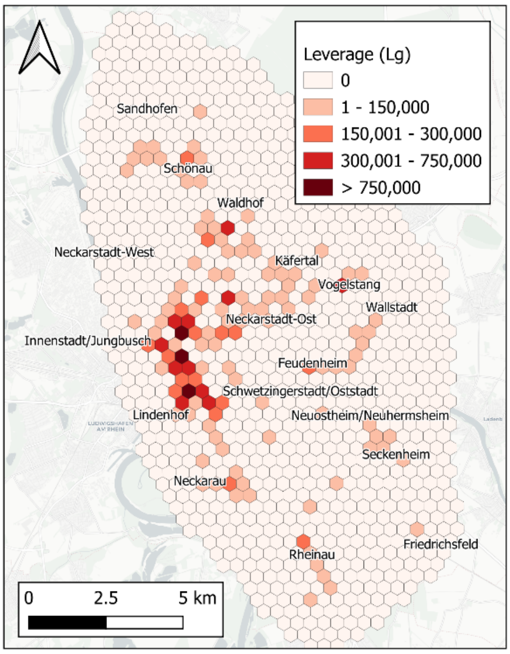


Figure 7: Spatial distribution of cumulative store leverage at t = 250 m aggregated to 500 x 500 m grid cells in Mannheim.