

Supplementary Materials for: Spatial Dependence and Urban Facility Context of Public Library Use Intensity: Evidence from Seven Metropolitan Cities in South Korea

This document combines Supplementary Tables S1 through S7 referenced in the main manuscript. No Supplementary Figure S1 or Video S1 is included in this submission package.

Table S1. Variance inflation factor diagnostics for the 17-variable predictor set.

No.	Variable	Variable_code	VIF	Note
1	Cafes (1 km)	cafes_1km	3.53	Spatial predictor
2	Cafes (2 km)	cafes_2km	4.36	Spatial predictor
3	Cinemas (1 km)	cinemas_1km	2.06	Spatial predictor
4	Cinemas (2 km)	cinemas_2km	3.09	Spatial predictor
5	Supermarkets (1 km)	supermarkets_1km	3.8	Spatial predictor
6	Supermarkets (2 km)	supermarkets_2km	5.1	Spatial predictor
7	Subway stations (1 km)	subway_stations_1km	3.36	Spatial predictor
8	Subway stations (2 km)	subway_stations_2km	4.97	Spatial predictor
9	Bus stops (1 km)	bus_stops_1km_model	6.3	Spatial predictor
10	Bus stops (2 km)	bus_stops_2km_model	8.88	Spatial predictor
11	Academies (1 km)	academies_1km_model	3.11	Spatial predictor
12	Academies (2 km)	academies_2km_model	3.72	Spatial predictor
13	Elementary schools (1 km)	schools_elementary_1km	2.17	Spatial predictor
14	Middle schools (1 km)	schools_middle_1km	1.78	Spatial predictor
15	High schools (1 km)	schools_high_1km	1.54	Spatial predictor

16	Parks (1 km)	parks_1km	1.32	Spatial predictor
17	Park area, m ² (1 km)	park_area_1km_m2	1.12	Spatial predictor
18	City FE: Daegu	city_daegu	2.39	City fixed effect
19	City FE: Daejeon	city_daejeon	1.91	City fixed effect
20	City FE: Gwangju	city_gwangju	2.23	City fixed effect
21	City FE: Incheon	city_incheon	1.65	City fixed effect
22	City FE: Seoul	city_seoul	3.7	City fixed effect
23	City FE: Ulsan	city_ulsan	1.57	City fixed effect

Table S2. K-nearest-neighbor sensitivity analysis (KNN-5, KNN-6, KNN-8, KNN-10).

Model	K	n	OLS_R2	OLS_AIC	OLS_MI	OLS_MI_p	SAR_rho	SAR_R2	SAR_AIC	SAR_MI	SAR_MI_p	RLM_Lag	RLM_Lag_sig
Visit	5	335	0.44	3987.9	0.126	0.002	0.41	0.51	3954.9	-0.051	0.061	36.89	***
Visit	6	335	0.44	3987.9	0.117	0.002	0.443	0.514	3952.2	-0.043	0.074	39.77	***
Visit	8	335	0.44	3987.9	0.095	0.001	0.48	0.516	3950.5	-0.046	0.04	50.52	***
Visit	10	335	0.44	3987.9	0.087	0.001	0.486	0.513	3950.7	-0.049	0.016	52.71	***
Loans	5	320	0.299	3605.4	0.126	0.002	0.403	0.372	3581.8	-0.015	0.36	20.02	***
Loans	6	320	0.299	3605.4	0.12	0.001	0.413	0.369	3582.5	-0.009	0.425	15.68	***
Loans	8	320	0.299	3605.4	0.092	0.002	0.421	0.36	3584.9	-0.015	0.303	22.53	***
Loans	10	320	0.299	3605.4	0.075	0.001	0.425	0.357	3585.8	-0.019	0.239	27.32	***

Table S3. GWR local coefficients for cafe, cinema, bus-stop, subway-station, and high-school density by metropolitan city.

Outcome variable	Predictor variable	Metropolitan city	n	Mean coefficient	SD	Sig. positive (n)	Sig. negative (n)
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Visits per m2	Cafe density (1 km)	Seoul	136	50.3	0.18	136	0
Visits per m2	Cafe density (1 km)	Busan	49	-11.73	0.15	0	0
Visits per m2	Cafe density (1 km)	Daegu	39	-8.17	1.63	0	0
Visits per m2	Cafe density (1 km)	Incheon	34	49.58	0.44	34	0
Visits per m2	Cafe density (1 km)	Gwangju	31	-5.64	0.17	0	0
Visits per m2	Cafe density (1 km)	Daejeon	25	45.8	2.0	25	0
Visits per m2	Cafe density (1 km)	Ulsan	21	-11.96	0.17	0	0
Visits per m2	Cinema density (2 km)	Seoul	136	-22.87	0.12	0	136
Visits per m2	Cinema density (2 km)	Busan	49	-0.22	0.02	0	0
Visits per m2	Cinema density (2 km)	Daegu	39	-1.0	0.13	0	0
Visits per m2	Cinema density (2 km)	Incheon	34	-23.29	0.17	0	34
Visits per m2	Cinema density (2 km)	Gwangju	31	0.3	0.08	0	0
Visits per m2	Cinema density (2 km)	Daejeon	25	-22.46	0.82	0	25
Visits per m2	Cinema density (2 km)	Ulsan	21	-0.23	0.04	0	0
Visits per m2	Bus-stop density (1 km)	Seoul	136	-22.28	0.47	0	136
Visits per m2	Bus-stop density (1 km)	Busan	49	-7.89	0.19	0	0
Visits per m2	Bus-stop density (1 km)	Daegu	39	-8.44	0.26	0	0
Visits per m2	Bus-stop density (1 km)	Incheon	34	-20.63	0.78	0	34

	km)						
Visits per m2	Bus-stop density (1 km)	Gwangju	31	-0.06	0.36	0	0
Visits per m2	Bus-stop density (1 km)	Daejeon	25	-5.38	1.81	0	0
Visits per m2	Bus-stop density (1 km)	Ulsan	21	-8.91	0.16	0	0
Visits per m2	Subway-station density (2 km)	Seoul	136	9.25	0.21	0	0
Visits per m2	Subway-station density (2 km)	Busan	49	0.2	0.05	0	0
Visits per m2	Subway-station density (2 km)	Daegu	39	0.28	0.16	0	0
Visits per m2	Subway-station density (2 km)	Incheon	34	10.09	0.43	0	0
Visits per m2	Subway-station density (2 km)	Gwangju	31	-3.58	0.3	0	0
Visits per m2	Subway-station density (2 km)	Daejeon	25	13.65	0.84	0	0
Visits per m2	Subway-station density (2 km)	Ulsan	21	0.4	0.02	0	0
Visits per m2	High-school density (1 km)	Seoul	136	-10.46	0.11	0	0
Visits per m2	High-school density (1 km)	Busan	49	12.26	0.17	0	0
Visits per m2	High-school density (1 km)	Daegu	39	12.35	0.18	0	0
Visits per m2	High-school density (1 km)	Incheon	34	-10.13	0.13	0	0

Visits per m2	High-school density (1 km)	Gwangju	31	4.97	0.28	0	0
Visits per m2	High-school density (1 km)	Daejeon	25	-2.85	1.25	0	0
Visits per m2	High-school density (1 km)	Ulsan	21	13.13	0.14	0	0
Loans per m2	Cafe density (1 km)	Seoul	137	13.63	8.85	90	0
Loans per m2	Cafe density (1 km)	Busan	49	-6.18	0.32	0	0
Loans per m2	Cafe density (1 km)	Daegu	35	-0.92	0.38	0	0
Loans per m2	Cafe density (1 km)	Incheon	42	-4.71	5.97	0	0
Loans per m2	Cafe density (1 km)	Gwangju	24	-11.15	0.01	0	0
Loans per m2	Cafe density (1 km)	Daejeon	18	9.11	4.83	0	0
Loans per m2	Cafe density (1 km)	Ulsan	15	-4.58	0.21	0	0
Loans per m2	Cinema density (2 km)	Seoul	137	-15.1	5.56	0	64
Loans per m2	Cinema density (2 km)	Busan	49	-12.04	0.26	0	0
Loans per m2	Cinema density (2 km)	Daegu	35	-15.49	0.22	0	0
Loans per m2	Cinema density (2 km)	Incheon	42	-7.74	2.3	0	0
Loans per m2	Cinema density (2 km)	Gwangju	24	0.97	0.14	0	0
Loans per m2	Cinema density (2 km)	Daejeon	18	-3.25	1.47	0	0
Loans per m2	Cinema density (2 km)	Ulsan	15	-13.25	0.15	0	0
Loans per m2	Bus-stop density (1	Seoul	137	-16.02	9.68	0	68

	km)						
Loans per m2	Bus-stop density (1 km)	Busan	49	5.01	0.07	0	0
Loans per m2	Bus-stop density (1 km)	Daegu	35	3.07	0.27	0	0
Loans per m2	Bus-stop density (1 km)	Incheon	42	-2.13	2.37	0	0
Loans per m2	Bus-stop density (1 km)	Gwangju	24	4.01	0.65	0	0
Loans per m2	Bus-stop density (1 km)	Daejeon	18	-5.58	1.63	0	0
Loans per m2	Bus-stop density (1 km)	Ulsan	15	4.94	0.07	0	0
Loans per m2	Subway-station density (2 km)	Seoul	137	3.07	6.26	1	0
Loans per m2	Subway-station density (2 km)	Busan	49	-8.76	0.09	0	0
Loans per m2	Subway-station density (2 km)	Daegu	35	-9.32	0.38	0	0
Loans per m2	Subway-station density (2 km)	Incheon	42	22.6	2.21	17	0
Loans per m2	Subway-station density (2 km)	Gwangju	24	-20.56	0.63	0	0
Loans per m2	Subway-station density (2 km)	Daejeon	18	25.24	5.04	0	0
Loans per m2	Subway-station density (2 km)	Ulsan	15	-8.59	0.09	0	0
Loans per m2	High-school density (1 km)	Seoul	137	0.42	10.2	16	0

Loans per m2	High-school density (1 km)	Busan	49	-1.98	0.14	0	0
Loans per m2	High-school density (1 km)	Daegu	35	2.02	0.35	0	0
Loans per m2	High-school density (1 km)	Incheon	42	2.85	1.42	0	0
Loans per m2	High-school density (1 km)	Gwangju	24	-3.81	0.22	0	0
Loans per m2	High-school density (1 km)	Daejeon	18	-7.89	2.5	0	0
Loans per m2	High-school density (1 km)	Ulsan	15	-1.11	0.16	0	0

Table S4. Robustness of the academy-density association under alternative spatial-weights matrices (Voronoi contiguity and 2 km distance band).

Outcome variable	Spatial weights specification	n	OLS R2	OLS residual Moran's I	OLS residual Moran's I (p)	Robust LM-Lag (p)	Robust LM-Error (p)	SAR rho	Academy density (1 km) SAR beta	Academy density (1 km) SAR z	Academy density (1 km) SAR (p)	SAR residual Moran's I	SAR residual Moran's I (p)	Libraries dropped as islands (n)
Visits per m2	KNN-8 (primary)	335	0.44	0.095	0.003	<0.001	<0.001	0.48	27.12	3.49	<0.001	-0.046	0.036	0
Visits per m2	Voronoi rook contiguity	335	0.44	0.07	0.018	<0.001	<0.001	0.361	25.07	3.15	0.002	-0.082	0.004	0
Visits per m2	2 km distance band	274	0.444	0.1	0.045	0.003	0.023	0.148	29.39	3.28	0.001	-0.045	0.216	61
Loans per m2	KNN-8 (primary)	320	0.299	0.092	0.001	<0.001	0.009	0.421	14.97	2.61	0.009	-0.015	0.334	0
Loans per m2	Voronoi rook	320	0.299	0.079	0.014	<0.001	0.011	0.276	15.2	2.6	0.009	-0.021	0.285	0

	contiguity													
Loans per m2	2 km distance band	259	0.311	0.117	0.040	0.007	0.029	0.145	14.46	2.29	0.022	-0.033	0.362	61

Table S5. Negative Binomial robustness check for visits, loans, and borrowers using library floor area as an exposure.

Outcome variable (ratio framing)	Raw count variable used	n	Poisson dispersion (Pearson chi2/df)	Negative Binomial dispersion (alpha)	Academy density (1 km) IRR, NB (pre-MESF)	Academy density (1 km) p, NB (pre-MESF)	NB residual Moran's I (pre-MESF)	NB residual Moran's I (p, pre-MESF)	MESF eigenvectors added (n)	Academy density (1 km) IRR, final	Academy density (1 km) p, final	Residual Moran's I, final	Residual Moran's I (p), final
Visits per m2	Annual visits (count)	335	100355	0.508	1.096	0.219	0.075	0.004	8	1.105	0.173	0.04	0.052
Loans per m2	Annual loans (count)	335	28178	0.955	0.943	0.569	0.017	0.201	0	0.943	0.569	0.017	0.201
Borrowers per m2	Annual borrowers (count)	309	24968	0.98	0.981	0.863	-0.001	0.425	0	0.981	0.863	-0.001	0.425

Table S6. Comparison of libraries included versus excluded from the final analytical samples.

Outcome variable	n included	n excluded	City distribution chi2	City distribution chi2 (p)	Library type chi2	Library type chi2 (p)	Seats, median (included)	Seats, median (excluded)	Seats Mann-Whitney (p)	Floor area m2, median (included)	Floor area m2, median (excluded)	Floor area Mann-Whitney (p)	Logistic regression pseudo-R2	Logistic regression LLR (p)	Significant predictors of inclusion (p<0.05)
Visits per m2	335	150	54.35	<0.001	11.06	<0.001	180.0	81.0	<0.001	1370.0	574.0	<0.001	0.12	<0.001	Incheon (vs. Busan), Seoul (vs.

															Busan), Library type B (n=15 category), Seating capacity
Loans per m2	320	165	23.56	<0.001	8.93	0.003	181.5	87.0	<0.001	1370.0	847.64	<0.001	0.059	<0.001	Daegu (vs. Busan), Daejeon (vs. Busan), Gwangju (vs. Busan), Incheon (vs. Busan), Seoul (vs. Busan), Ulsan (vs. Busan), Library type B (n=15 category)
Borrower s per m2	320	165	23.56	<0.001	8.93	0.003	181.5	87.0	<0.001	1370.0	847.64	<0.001	0.059	<0.001	Daegu (vs. Busan), Daejeon (vs. Busan), Gwangju (vs. Busan), Incheon (vs. Busan), Seoul (vs. Busan), Ulsan (vs. Busan), Library

Table S7. Robustness of the academy-density association to a seating-capacity control variable.

Outcome variable	Specification	Variable	Coefficient	z	p
Borrowers per m2	SAR, baseline (no seats)	Academy density (1 km)	-0.27	-0.2	0.842
Borrowers per m2	SAR, baseline (no seats)	Academy density (2 km)	6.45	4.29	<0.001
Borrowers per m2	SAR, with seating capacity control	Academy density (1 km)	-0.43	-0.32	0.749
Borrowers per m2	SAR, with seating capacity control	Academy density (2 km)	6.55	4.37	<0.001
Borrowers per m2	SAR, with seating capacity control	Seating capacity	-1.77	-2.09	0.037
Loans per m2	SAR, baseline (no seats)	Academy density (1 km)	14.97	2.61	0.009
Loans per m2	SAR, baseline (no seats)	Academy density (2 km)	8.92	1.39	0.163
Loans per m2	SAR, with seating capacity control	Academy density (1 km)	13.75	2.45	0.014
Loans per m2	SAR, with seating capacity control	Academy density (2 km)	9.78	1.55	0.120
Loans per m2	SAR, with seating capacity control	Seating capacity	-13.31	-3.75	<0.001
Visits per m2	SAR, baseline (no seats)	Academy density (1 km)	27.12	3.49	<0.001
Visits per m2	SAR, baseline (no seats)	Academy density (2 km)	6.03	0.7	0.485
Visits per m2	SAR, with seating capacity control	Academy density (1 km)	25.81	3.35	<0.001

Visits per m2	SAR, with seating capacity control	Academy density (2 km)	6.17	0.72	0.470
Visits per m2	SAR, with seating capacity control	Seating capacity	-12.29	-2.66	0.008