

Supplementary File S2: Cluster diagnostics

Table S2.1. Diagnostic indices for alternative k-means solutions

Cluster s	WSS	BSS	Explained variance	Residual variance	Average silhouette	Davies- Bouldin	Smallest cluster	Largest cluster
2	1277.82	518.18	0.289	0.711	0.275	1.438	160	290
3	1079.80	716.20	0.399	0.601	0.203	1.508	129	170
4	942.48	853.52	0.475	0.525	0.193	1.467	71	129
5	839.37	956.63	0.533	0.467	0.199	1.366	60	103
6	770.34	1025.66	0.571	0.429	0.200	1.352	32	103
7	715.03	1080.97	0.602	0.398	0.192	1.364	29	86
8	670.61	1125.39	0.627	0.373	0.193	1.303	22	84
9	629.39	1166.61	0.650	0.350	0.197	1.310	19	76
10	595.36	1200.64	0.669	0.331	0.187	1.388	17	66

Note. WSS = total within-cluster sum of squares; BSS = between-cluster sum of squares. Higher average silhouette values and lower Davies-Bouldin values indicate better separation. The selected four-cluster solution is shown in bold.

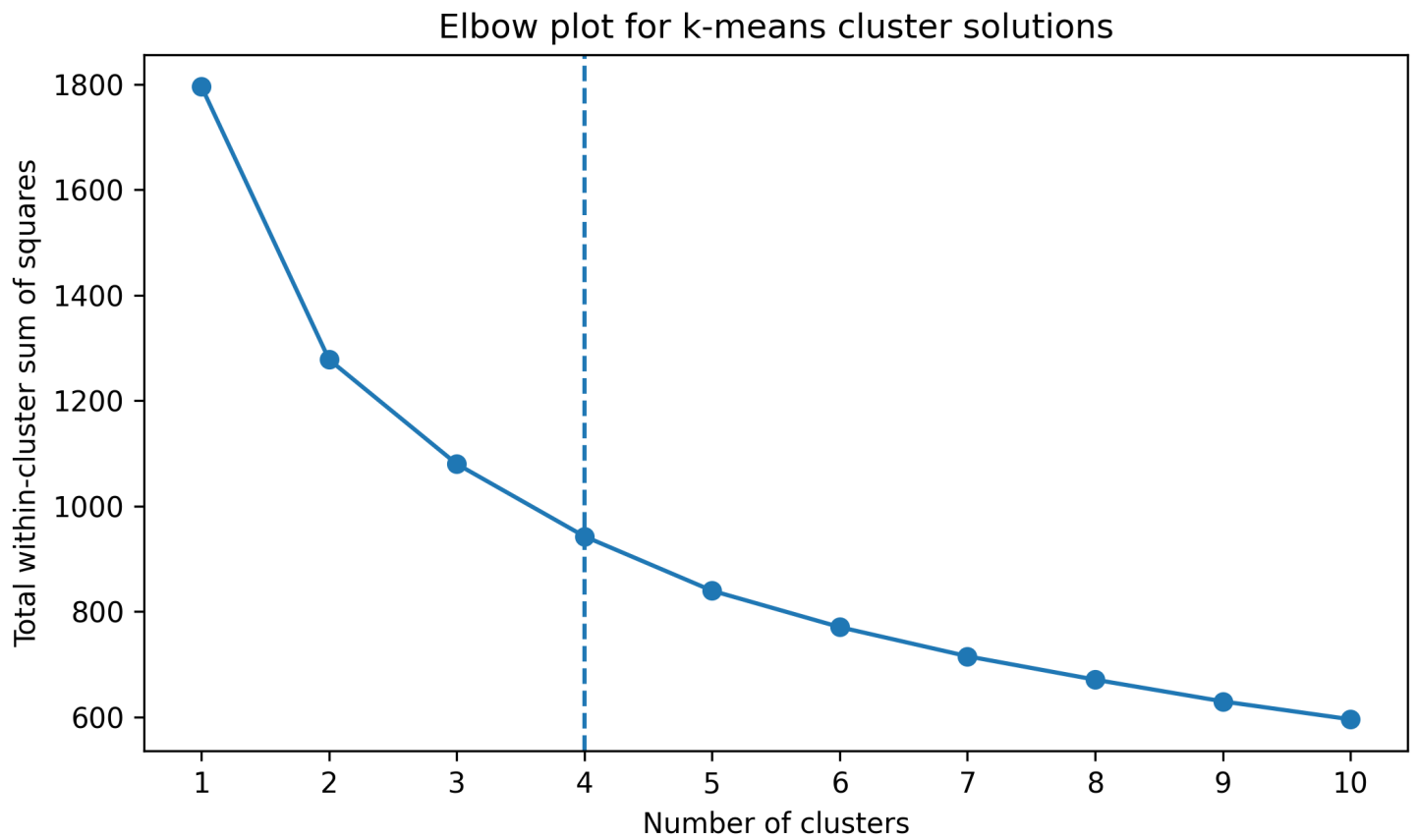


Figure S2.1. Elbow plot for alternative k-means solutions. The dashed vertical line identifies the retained four-cluster solution. WSS decreased progressively as the number of clusters increased, with diminishing incremental reductions after approximately four clusters.

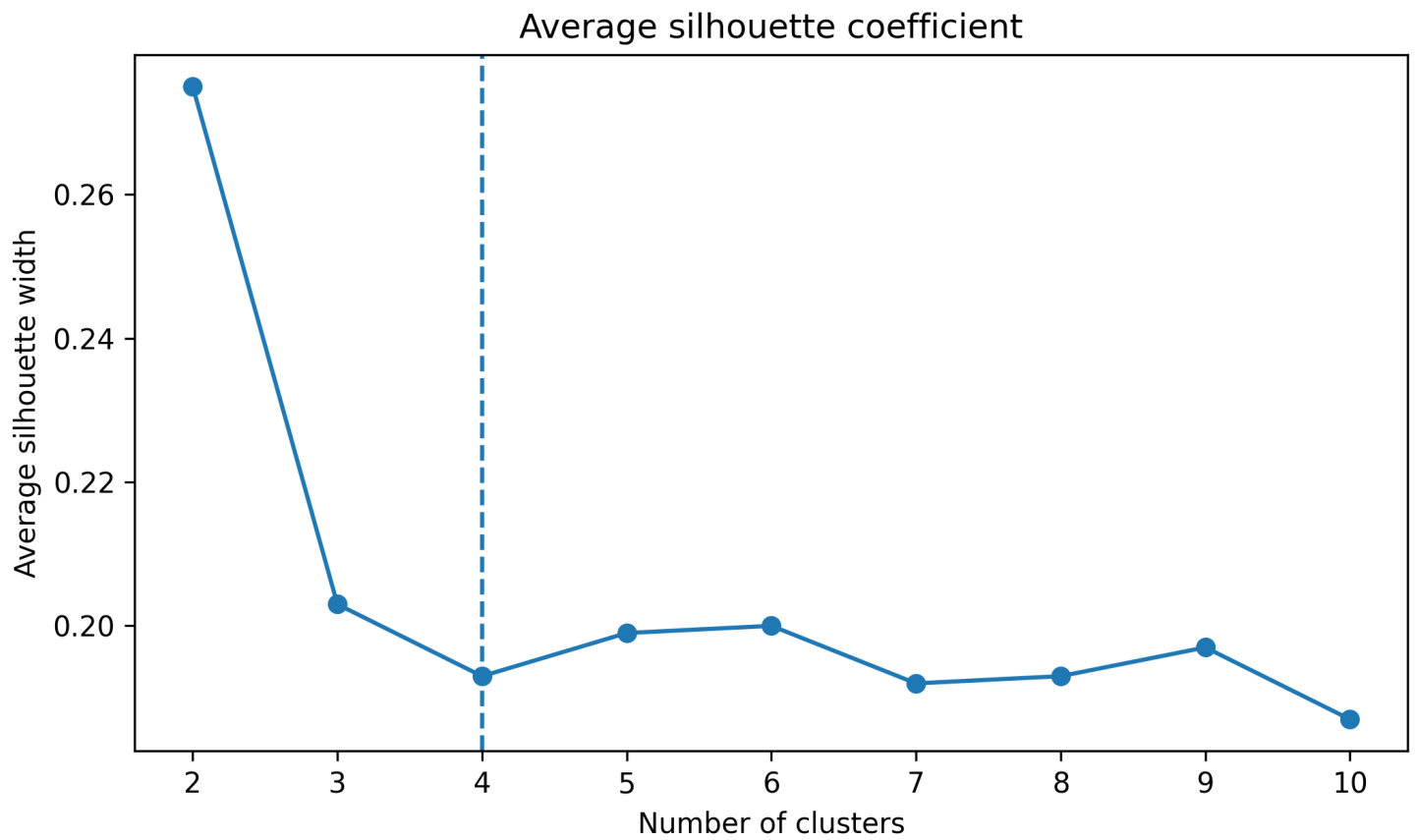


Figure S2.2. Average silhouette width across alternative k-means solutions. Higher values indicate greater within-cluster cohesion and between-cluster separation. The highest value was observed for two clusters; the dashed vertical line identifies the retained four-cluster solution.

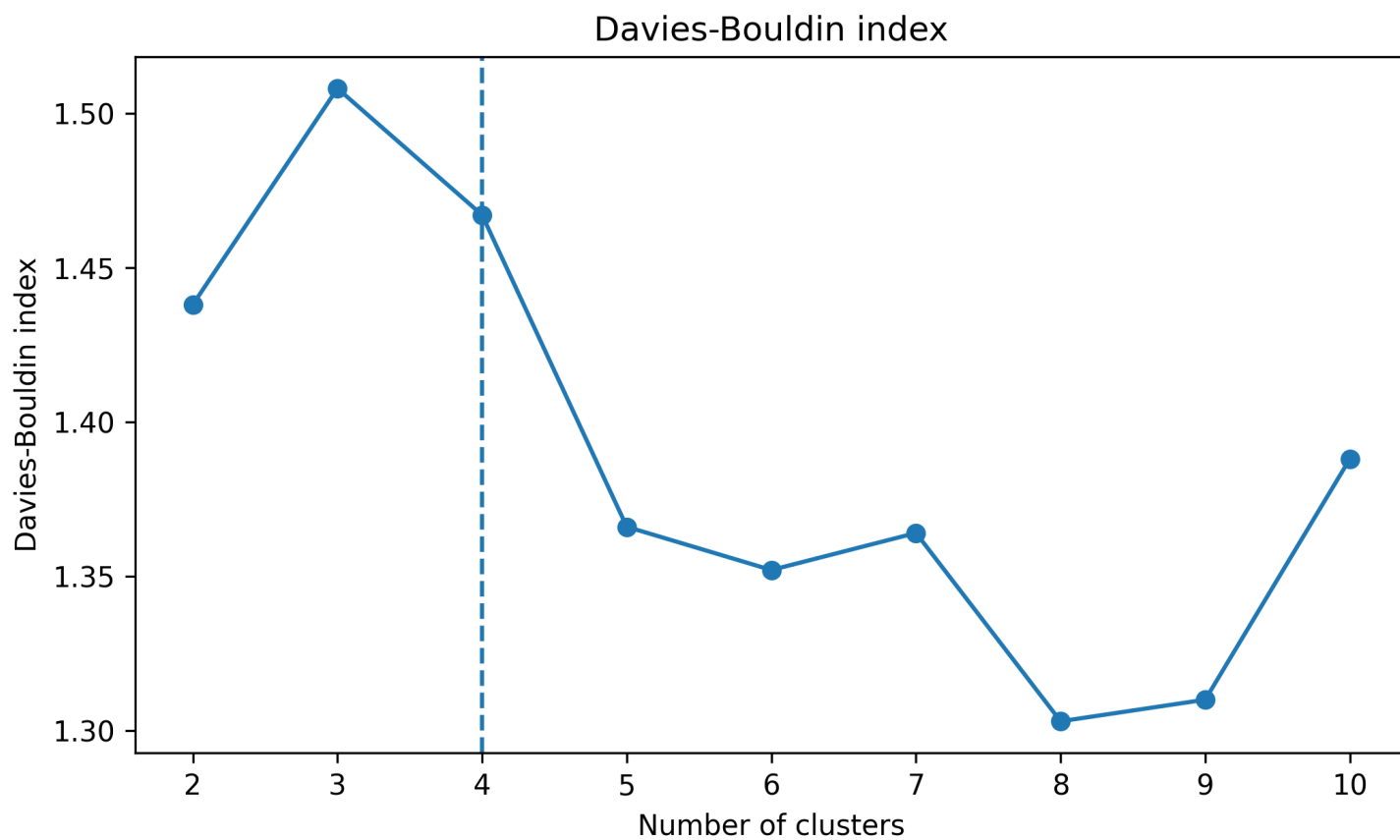


Figure S2.3. Davies-Bouldin index across alternative k-means solutions. Lower values indicate better separation. The lowest value was observed for eight clusters; the dashed vertical line identifies the retained four-cluster solution.