Grid Plan Validation Checklist
(Geometry-Style Coordinates, 4-Neighbor Adjacency)

Variables & Contract (fixed for the sandbox)

- Grid: width W, height H, nodes $N = W \cdot H$.
- Coordinates: origin at bottom-left, (x, y) with $x \to$ right, $y \to$ up.
- Node ID: $\text{id} = y \cdot W + x$ (row-major with upward y).
- Adjacency: **4-neighbor** (Manhattan distance = 1), no wrap.
- Districts: K, tolerance ε (e.g., 0.05), ideal population $P^* = \big(\sum \texttt{population}\big)/K$.
- Files to validate: `..._nodes.csv`, `..._edges_grid.csv`, `..._partition_seeded.csv`.

A) Preflight Invariants (lattice must be valid)

A1. Nodes table integrity ☐ PASS ☐ FAIL

1. Count is exactly N.
2. `id` covers $0, \ldots, N-1$ with no gaps or duplicates.
3. (x, y) are in bounds: $0 \le x < W$, $0 \le y < H$, and are unique per `id`.
4. Spot-check the mapping: for several rows, confirm $\text{id} = yW + x$.

A2. Grid edges integrity ☐ PASS ☐ FAIL

1. Each edge (u, v) satisfies $u \neq v$ and endpoints are in $[0, N-1]$.
2. Edges are *only* 4-neighbor pairs: letting (x_u, y_u) and (x_v, y_v) be coordinates of u, v,
$$|x_u - x_v| + |y_u - y_v| = 1.$$
3. No duplicate undirected pairs; store one row with $u < v$.
4. Sanity edge count matches
$$E_4 = H(W-1) + W(H-1).$$

If A1 or A2 fails: stop and fix the lattice before checking any partition.

B) Partition File Integrity (hard checks)

B3. Coverage & uniqueness ☐ PASS ☐ FAIL

Every `id` appears exactly once in `__partition_seeded.csv`, with `district` $\in \{0, \ldots, K-1\}$ (no -1, no out-of-range).

B4. Non-empty districts ☐ PASS ☐ FAIL

For each district d, the set $V_d = \{\, \mathrm{id} : \texttt{district}(\mathrm{id}) = d \,\}$ satisfies $|V_d| \geq 1$.

C) Contiguity (hard check)

C5. One connected component per district ☐ PASS ☐ FAIL

For each d, consider the subgraph induced by V_d on the *grid* edges; require the number of connected components to be

$$\mathrm{components}_d = 1 \quad \forall d \in \{0, \ldots, K-1\}.$$

Any $\mathrm{components}_d > 1$ indicates an *island* $\Rightarrow$ invalid plan.

D) Population Balance (hard check)

D6. Deviation vs. ideal ☐ PASS ☐ FAIL

For each d, compute $\mathrm{Pop}_d = \sum_{v \in V_d} \texttt{population}(v)$ and

$$\mathrm{dev}_d = \frac{|\mathrm{Pop}_d - P^*|}{P^*}.$$

Require $\max_d \mathrm{dev}_d \leq \varepsilon$ and verify $\sum_d \mathrm{Pop}_d = \sum \texttt{population}$.

E) Cross-Edges & Perimeter (consistency & diagnostics)

E7. Cut-edge accounting (consistency) ☐ PASS ☐ FAIL

Let Cut be the number of grid edges whose endpoints lie in *different* districts. For each district d, let B_d be the number of its incident grid edges that cross to another district. Check the invariant:

$$\sum_{d=0}^{K-1} B_d = 2\,\mathrm{Cut}.$$

A mismatch indicates boundary accounting bugs.

E8. Perimeter (diagnostic)

Optionally compute $\mathrm{Perimeter}_d = B_d + (\#$ outer-border edges touching $d)$ as a compactness proxy; record values but do not gate on them here.

F) Hole (Enclave) Test (policy choice)

F9. No holes inside a district ☐ PASS ☐ WARN/ ALLOW

Flood-fill the complement of V_d from the rectangle boundary; if the complement has > 1 component, district d contains an enclave (a "hole").
Policy (choose one and document):

- **Strict**: forbid holes ⇒ any hole ⇒ FAIL.
- **Lenient**: allow holes ⇒ WARN only (common in research).

G) Determinism & Reproducibility (pipeline hard check)

G10. Deterministic rebuild ☐ PASS ☐ FAIL

Re-run the same seed-and-grow procedure with the same RNG seed and tie-break rule (e.g., smaller y then x). Require the *exact* same assignment vector. Optionally compute a plan hash (e.g., SHA-256 of the district label vector) and compare.

H) Visual QA (human-in-the-loop, but mandatory)

H11. Two plots ☐ PASS ☐ FAIL

- **District map**: color by district, overlay grid boundaries; verify no islands/stray cells.
- **Opinion heatmap**: underlying opinion field looks plausible (gradients/blocs); borders not obviously broken.

I) Acceptance Summary

A plan is **ACCEPTED** if and only if:

- A1–A2 PASS (lattice integrity),
- B3–B4 PASS (coverage & non-empty),
- C5 PASS (contiguity),
- D6 PASS (population balance),
- E7 invariant holds (boundary consistency),
- G10 PASS (determinism),
- F9 satisfies your declared policy,
- H11 looks sane to a human inspector.

Record on acceptance (attach to plan):

Metric	Value
Max deviation $\max_d \mathrm{dev}_d$	
Total cut edges Cut	
Boundary counts $\{B_d\}$	
Perimeters $\{\mathrm{Perimeter}_d\}$	
District populations $\{\mathrm{Pop}_d\}$	
Plan hash (e.g., SHA-256)	
Notes / anomalies	