



Digital Historical Communication Archaeology Framework for Youth Interpretation of Java War Heritage in Indonesia

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Abstract

Indonesia's districts and cities operate under a single decentralization framework yet differ sharply in fiscal capacity, human development, and infrastructure access. Using an author-compiled panel of 5,964 district-year observations for 2011–2022, long-run district means are computed, and 483 complete districts/cities are clustered on nine standardized indicators spanning fiscal structure, social capability, and energy–digital access. Internal indices favor three clusters, yet a four-cluster solution is retained because it separates an extreme-deprivation subgroup that $k = 3$ absorbs into a broader transition cluster. The regimes are metropolitan high-capacity, payroll-intensive convergence, capital-oriented transition, and infrastructure-deprived periphery. Poverty, excluded from cluster formation, differs strongly across regimes (Welch $F = 68.66$, $p < 0.001$). In heteroskedasticity-robust regressions controlling for income, demographic dependency, transfer dependence, and macro-region fixed effects, the peripheral regime records a poverty rate 8.06 percentage points above that of the metropolitan regime. The findings identify associations rather than causal effects and show that regional disadvantage is configurational: fiscal reform, infrastructure provision, and digital inclusion should be bundled differently across regimes rather than delivered as a uniform national package.

Keywords *Regional typology, Fiscal decentralization, Digital divide, Energy access, Poverty, Indonesia*

INTRODUCTION

Decentralization gives Indonesian local governments broadly similar formal responsibilities, yet the places expected to exercise them are far from similar. Metropolitan cities combine dense tax bases, skilled populations, and mature networks. Many non-metropolitan districts have nearly universal electricity but rely on transfers and spend heavily on personnel. Remote districts face simultaneous shortfalls in own-source revenue, education, electricity, clean household energy, and internet access. Treating these territories as points on a single development ladder obscures the fact that disadvantage arises from different combinations of constraints.

This heterogeneity matters for the post-2022 intergovernmental framework, which seeks to improve transfer design, local taxing powers, expenditure quality, and accountability (Lewis, 2023; Martinez-Vazquez et al., 2017). The question is no longer whether more resources should be decentralized, but whether common fiscal instruments can yield comparable results across territories with structurally different revenue bases, spending structures, capabilities, and infrastructure stocks. International evidence offers no reason to expect a uniform answer, because decentralization outcomes depend on local institutions, incentives, administrative capacity, and spending composition (Faguet, 2014; Martinez-Vazquez et al., 2017).

Three literatures address this problem but rarely intersect. Place-based scholarship argues that interventions should respond to territorially specific constraints rather than assume spatial neutrality (Barca et al., 2012; Iammarino et al., 2019; Rodríguez-Pose, 2018). Fiscal-decentralization research examines revenue autonomy, transfers, and expenditure, including the

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possibility that large fiscal resources do not translate into better services (Lewis, 2017, 2023; Martinez-Vazquez et al., 2017). A third strand shows that spatial inequality in electricity and digital connectivity interacts with skills and complementary capabilities (Acheampong et al., 2021; Cariolle, 2021; Dinkelman, 2011; Hjort & Poulsen, 2019; Kartiasih et al., 2023; Lythreatis et al., 2022; Salemink et al., 2017; van de Walle et al., 2017). Indonesian applications, however, usually treat one domain at a time, describe a single year, and validate clusters using outcomes that helped form them.

This paper presents a district/city panel for 2011–2022, reduced to long-run means, and applies k-means clustering to nine standardized fiscal, social, and energy–digital indicators, with external validation using poverty, which is excluded from clustering. Heteroskedasticity-robust regressions then include income, dependency, transfer dependence, and macro-region fixed effects. The analysis asks which stable regimes emerge among 483 districts/cities, how they are distributed geographically, and whether their poverty differences survive structural controls.

LITERATURE REVIEW

Place-based development and fiscal decentralization

Place-based development holds that the productivity and inclusion effects of policy depend on local institutions, capabilities, networks, and settlement structures. The approach is explicitly distinguished from spatially neutral intervention (Barca et al., 2012), and regional inequality is not a temporary deviation that mobility will remove (Iammarino et al., 2019). Left-behindness may reflect cumulative causation, in which weak markets reduce investment, out-migration thins the skills base, and diminished fiscal capacity constrains public action. Therefore, policy must be matched to the function and constraints of the target territory (Fiorentino et al., 2024; Iammarino et al., 2019; Rodríguez-Pose, 2018).

Fiscal decentralization is one mechanism for that matching: own-source revenue grants discretion and strengthens tax–service accountability; transfers equalize fiscal capacity; and expenditure autonomy permits a locally appropriate mix of infrastructure and services (Faguet, 2014; Martinez-Vazquez et al., 2017). The theory is conditional. Thin tax bases leave transfers dominant, and rigid recurrent personnel costs can leave nominal autonomy without room for maintenance or productive capital, which helps explain mixed cross-country results (Martinez-Vazquez et al., 2017). Indonesia illustrates the ambiguity: substantial local resources may coexist with weak service delivery (Lewis, 2017), while the new framework targets incentives and spending quality rather than transfer volume alone (Lewis, 2023).

Energy, digital connectivity, and social capability

Reliable electricity and clean household energy ease time, health, and production constraints, but their returns depend on complementary assets. Quasi-experimental studies report employment or consumption gains from electrification in South Africa and India (Dinkelman, 2011; van de Walle et al., 2017), whereas cross-country evidence links energy access to human development, showing marked regional heterogeneity and, in some specifications, insignificant or adverse effects (Acheampong et al., 2021). Access is an enabling condition, not a sufficient development strategy.

The digital divide literature draws a parallel distinction among access, use, skills, and outcomes, with infrastructure gaps interacting with education, affordability, and connection quality (Lythreatis et al., 2022; Salemink et al., 2017). Rural areas face a double disadvantage because remoteness raises network costs while limited skills and market density reduce the returns to adoption (Salemink et al., 2017). For Indonesia, Kartiasih et al. (2023) document spatially uneven

digital development associated with education, income, population, and formal employment. Connectivity can widen market access (Cariolle, 2021) and shift employment (Hjort & Poulsen, 2019), but not mechanically.

Integrated framework and hypotheses

The integrated framework treats regional development as a configuration of mutually reinforcing capabilities, with poverty as a downstream outcome rather than a clustering input: Place endowments → fiscal room and spending mix → service and network access → human capability and productive inclusion → poverty

Macro-region, demographic dependency, and income per capita serve as conditioning factors, so the typology should identify regimes rather than rank districts along a single latent scale. Three hypotheses guide the external validation: metropolitan high-capacity districts have the lowest average poverty because autonomy, capability, density, and network access are jointly high (H1); infrastructure-deprived peripheral districts have the highest average poverty because low autonomy coincides with deficits in human development, energy, and internet access (H2); and these differentials persist after controlling for income, dependency, transfer dependence, and macro-region (H3).

RESEARCH METHOD

Data construction and analytical sample

The estimation archive is an author-compiled district/city panel of 5,964 observations for 2011–2022, merging socioeconomic indicators with local-government revenue and expenditure records. It follows series conventionally published by Statistics Indonesia and the Directorate General of Fiscal Balance, but table-level source metadata are not preserved and should be restored from the author's original data log before submission.

Consistency rules set urbanization above 100 and electricity or clean-energy access above 105 to missing, drop observations without total regional revenue, and exclude implausible GRDP per capita from the logarithmic control. The panel is then collapsed to district means, producing a structural cross-section that smooths temporary shocks and assigns each district a stable type. Of the 491 resulting records, eight with incomplete clustering variables are removed, leaving $N = 483$ across seven macro-regions: Java–Bali, Sumatra, Kalimantan, Sulawesi, Nusa Tenggara, Maluku, and Papua. Averaging removes within-district dynamics but avoids reclassification driven by project timing or survey noise.

Variables and operationalization

Nine standardized variables form the cluster space: own-source revenue, capital expenditure, and employee expenditure as shares of the relevant totals; the Human Development Index (HDI), mean years of schooling, and urbanization; and electricity, clean household energy, and internet access. Standardization ensures that percentage and index scales contribute equally to Euclidean distance. Transfer dependence is reserved for the econometric model, and poverty is excluded from clustering, making it a genuinely external outcome.

$$z_{ij} = (x_{ij} - \bar{x}_j) / s_j$$

Clustering model and selection of k

K-means partitions districts into k groups by minimizing the within-cluster sum of squared distances between standardized vectors z_i and the centroids μ_g :

$$\min \{C_1, \dots, C_k\} \sum_{g=1}^k \sum_{i \in C_g} \|z_i - \mu_g\|^2$$

Solutions for $k = 3, 4$, and 5 are compared using the Calinski–Harabasz (CH) index, the average silhouette coefficient, and the Davies–Bouldin index (DBI) (Caliński & Harabasz, 1974; Davies & Bouldin, 1979; Jain, 2010; Rousseeuw, 1987). Higher CH and silhouette values and a lower DBI indicate stronger separation, but no internal index is infallible when clusters differ in density or a policy-relevant subgroup is small (Gagolewski et al., 2021). Therefore, selection balances internal validity against stability, interpretability, and marginal policy information.

External validation and econometric specification

Poverty differences are tested using Welch’s heteroskedastic ANOVA (Welch, 1951) because Bartlett tests reject equal variances. Kruskal–Wallis serves as a distribution-free check, with Holm-adjusted pairwise comparisons and eta- and omega-squared effect sizes. HDI is not used for validation because it helped create the clusters. Three nested models are estimated with HC3 standard errors (MacKinnon & White, 1985), using Type 2 as the reference:

$Poverty_i = \alpha + \sum \beta_t Type_{it} + \gamma_1 \ln(GRDPpc_i) + \gamma_2 Dependency_i + \gamma_3 TransferDep_i + \mu_r + \varepsilon_i$
Model 1 includes only type indicators; Model 2 adds log GRDP per capita, the dependency ratio, and transfer dependence; Model 3 adds macro-region fixed effects and includes a log-poverty sensitivity check. Coefficients capture persistent differences across configurations, not the effect of moving a district between types.

FINDINGS AND DISCUSSION

Internal validity and the four-type decision

Table 1. Internal cluster-validity comparison

k	CH	Silhouette	DBI	Assessment
3	249.47	0.294	1.227	Statistical benchmark
4	224.81	0.255	1.281	Retained policy solution
5	200.23	0.257	1.274	No added clarity

Higher CH and silhouette and lower DBI are preferred; the metrics come from the saved cluster assignments.

Internal indices peak at $k = 3$, so a mechanical rule would select three clusters. The four-cluster solution is retained because the cross-classification shows what it adds: under $k = 3$, all 45 districts that become Type 4 are embedded in a broader cluster that also contains 94 Type 1 districts. The fourth centroid isolates districts with much lower HDI, electricity, clean energy, internet access, and fiscal autonomy, and markedly higher poverty. The cost is weaker average separation; the benefit is a territorially concentrated policy regime that would otherwise disappear. The paper therefore reports $k = 3$ as the statistical benchmark and $k = 4$ as the policy solution.

Regime profiles

Table 2. Fiscal structure of the four regimes

Type	Label	n	Share %	Autonomy %	Capital %	Employee %
1	Capital-oriented transition	164	34.0	6.19	24.57	37.74
2	Metropolitan high capacity	97	20.1	21.12	20.37	45.66
3	Payroll-intensive convergence	177	36.6	10.61	17.21	47.69
4	Infrastructure-deprived periphery	45	9.3	3.36	26.50	28.93

Table 3. Social, infrastructure, and external-outcome profile

Type	HDI	Urban %	Electricity %	Clean energy %	Internet %	Poverty %
1	66.37	26.58	91.91	45.98	35.87	12.41
2	76.31	92.71	99.33	79.05	64.15	7.60
3	67.82	38.71	97.76	65.55	41.35	11.38
4	57.77	13.27	58.10	19.62	16.62	22.34

Poverty is reported for external characterization and was not used in clustering.

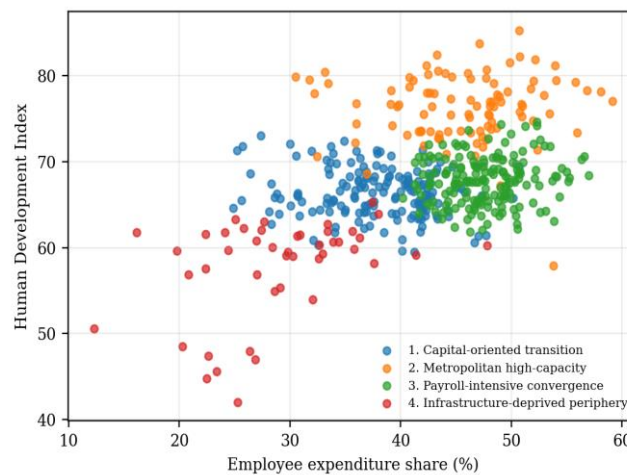


Figure 1. District/city typology in the HDI–employee-expenditure plane. Illustrative plot; clustering uses nine standardized dimensions.

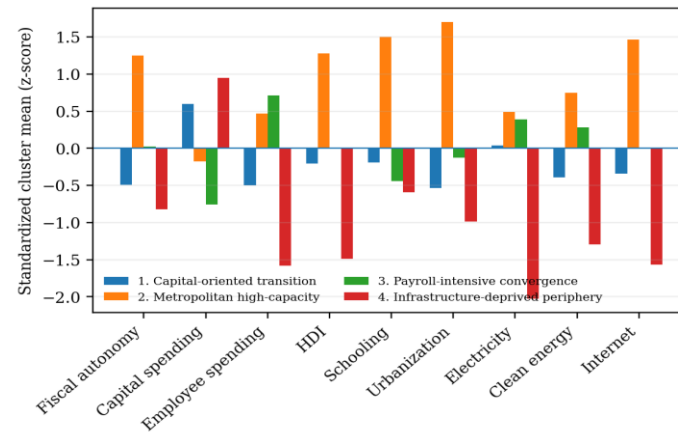


Figure 2. Standardized nine-variable profiles. Positive values indicate a cluster mean above the national district/city mean.

The four profiles are qualitatively distinct. Type 1, capital-oriented transition districts (164; 34.0%), combines a relatively high share of capital expenditures with very low fiscal autonomy, moderate electricity access, weak clean-energy access, and limited internet penetration. The label reflects an expenditure orientation, not verified capital effectiveness.

Type 2, metropolitan high-capacity districts and cities (97; 20.1%), leads on nearly every dimension and records the lowest poverty rate at 7.60%; its high employee share shows that payroll intensity need not imply weak outcomes when the revenue base and complementary capabilities are strong.

Type 3, payroll-intensive convergence districts (177; 36.6%), is the largest regime, with the highest employee share and the lowest capital share. Electricity is nearly universal, and clean-energy access is comparatively strong, but human development, schooling (8.02 years), urbanization, and internet access remain well below those in Type 2, so basic network thresholds have been crossed without productive digital inclusion.

Type 4, infrastructure-deprived peripheral districts (45; 9.3%), is small but decisive: it ranks lowest on every fiscal, social, and network indicator and averages 22.34% poverty, almost three times the Type 2 mean.

Geography of the regimes

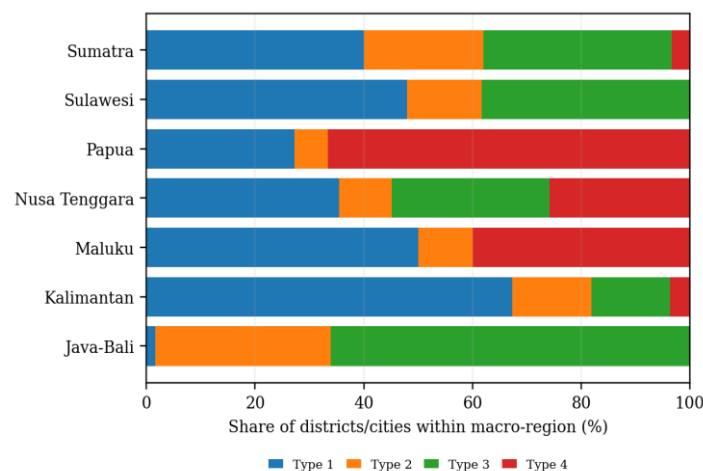


Figure 3. Regime composition within Indonesia's macro-regions

Geography is orderly rather than random. Java-Bali contains no Type 4 districts and is dominated by Type 3 (66.12%) and Type 2 (32.23%), with nearly half of all Type 2 districts located there. Type 1 dominates Kalimantan (67.27%) and is prominent in Sulawesi (47.95%) and Sumatra (40.00%), forming a non-metropolitan transition belt. Type 4 is concentrated in the eastern periphery: 66.67% of Papua's observed districts, 40.00% of Maluku, and 25.81% of Nusa Tenggara, with Papua alone accounting for 48.89% of all Type 4 cases. The typology thus captures a center-periphery structure while retaining variation outside Java.

External poverty validation

Poverty varies markedly across the four regimes. Welch's ANOVA yields $F(3, 158.54) = 68.66$, $p < 0.001$; Kruskal-Wallis yields the same conclusion ($H = 120.19$, $p < 0.001$); and the between-type effect is large ($\eta^2 = 0.341$; $\omega^2 = 0.336$). Holm-adjusted pairwise tests reject equality for every pair except Type 1 versus Type 3 (adjusted $p = 0.074$), which is informative because these regimes have similar poverty despite different expenditure and infrastructure profiles.

Table 4. Poverty associations by territorial regime

Variable	M1	M2	M3
Type 1	4.813*** (0.578)	2.754*** (0.632)	3.501*** (0.612)
Type 3	3.777*** (0.435)	1.943*** (0.522)	1.818*** (0.522)
Type 4	14.744*** (1.266)	10.563*** (1.483)	8.063*** (1.378)
ln GRDP pc	—	-2.385*** (0.481)	-1.660*** (0.419)
Dependency	—	0.183*** (0.042)	0.112*** (0.039)
Transfer dep.	—	0.024 (0.026)	0.063** (0.028)
Controls	No	Yes	Yes
Region FE	No	No	Yes
N	483	483	483
R ²	0.341	0.440	0.563

Reference: Type 2 (metropolitan high capacity). HC3 robust standard errors in parentheses.

* $p < 0.01$, $p < 0.05$, * $p < 0.10$.

Model 1 reproduces raw gaps of 4.81, 3.78, and 14.74 percentage points for Types 1, 3, and 4 relative to Type 2. Adding income, dependency, and transfer dependence narrows but does not eliminate these gaps; in Model 3 with macro-region fixed effects, the gaps remain at 3.50, 1.82, and 8.06 points, all significant. Higher log GRDP per capita is associated with lower poverty, and higher dependency with higher poverty. Transfer dependence becomes positive and significant only when macro-region is held constant, suggesting that it partly proxies territorial structure. A log-poverty check preserves the ordering of the coefficients, and variance-inflation factors below three indicate no severe multicollinearity. H1–H3 are supported as conditional associations, not treatment effects.

Interpretation and policy implications

Regional inequality in Indonesia is configurational rather than ordinal. Type 2 is distinguished not by a single superior indicator but by the joint presence of fiscal autonomy, urban density, schooling, human development, and near-universal networks, consistent with place-based

accounts of cumulative advantage (Barca et al., 2012; Iammarino et al., 2019; Rodríguez-Pose, 2018). Type 3 sharpens the fiscal-composition debate because payroll-intensive budgets coexist with moderate human-development and internet profiles, which is compatible with evidence that substantial local resources can have weak service outcomes when incentives and implementation quality are misaligned (Lewis, 2017).

Type 1 shows that a high capital share need not outperform, echoing warnings that infrastructure spending alone underperforms when institutions, maintenance, skills, and market links are weak (Barca et al., 2012; Iammarino et al., 2019; Lewis, 2017). Type 4 reconciles very high capital shares with the lowest stocks when expenditure is treated as a flow and access as an accumulated stock: unit costs are high, inherited deficits severe, projects multi-year, and administrative capacity constrained. This is precisely the group lost under $k = 3$. The cross-section cannot rule out reverse causality or omitted geography.

Table 5. Regime-specific policy portfolio

Regime	Priority policy package	Monitoring focus
Type 1: capital-oriented transition	Raise project quality rather than the capital ratio; strengthen revenue administration; fund maintenance; link assets to markets and productive internet use.	Completion and utilization; maintenance backlog; own-source revenue effort.
Type 2: metropolitan high capacity	Shift from basic access to quality, resilience, and digital innovation; target deprived neighborhoods.	Service reliability; intra-urban access gaps; productivity and externalities.
Type 3: payroll-intensive convergence	Rebalance rigid recurrent spending; improve workforce deployment; pair networks with skills and firm adoption; use performance-linked transfers.	Frontline productivity; learning and health outcomes; digital adoption.
Type 4: infrastructure-deprived periphery	Deliver an asymmetric minimum-service package (electricity, clean energy, broadband, logistics, schooling, administration) with multi-year, cost-adjusted funding.	Reliable rather than nominal access; cost per beneficiary; project continuity; staff presence.

The implication is not to replace formula-based equalization with discretion, but to embed territorial regimes in program design through differentiated service-cost parameters, co-financing rates, technical-assistance requirements, and output indicators. Monitoring must move beyond input shares, since a high capital share can signal effort, a small recurrent denominator, or weak execution. Performance systems should link fiscal inputs to completion, reliability, and utilization, and supplement nominal coverage with quality, affordability, and skills.

CONCLUSIONS

Using long-run averages for 2011–2022, this paper identifies four development regimes among 483 Indonesian districts and cities: metropolitan high-capacity areas with the lowest poverty; payroll-intensive convergence districts with strong basic infrastructure but moderate social and digital outcomes; capital-oriented transition districts that invest heavily while maintaining weak autonomy and connectivity; and infrastructure-deprived peripheral districts with simultaneous deficits and by far the highest poverty.

External validation is strong. Poverty differs across regimes under heteroskedastic and non-parametric tests, and the peripheral gap remains approximately 8.06 percentage points after

controls for income, demographic dependency, transfer dependence, and macro-region. The results support differentiated policy packages, but they do not establish that cluster membership causes poverty.

LIMITATIONS & FURTHER RESEARCH

Four limitations qualify the findings: long-run means suppress temporal change; k-means imposes spherical partitions, and $k = 3$ remains statistically stronger; spatial dependence and contiguity are not modeled; and the archive lacks complete source metadata, so the clean-energy definition should be verified before submission. Future work should estimate time-varying regime transitions, test spatially constrained clustering, and evaluate whether type-specific responses improve outcomes. Even so, the four-regime solution offers a disciplined alternative to one-size-fits-all decentralization: similar poverty levels can arise from different bottlenecks.

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