Journal of Zhejiang University-SCIENCE A

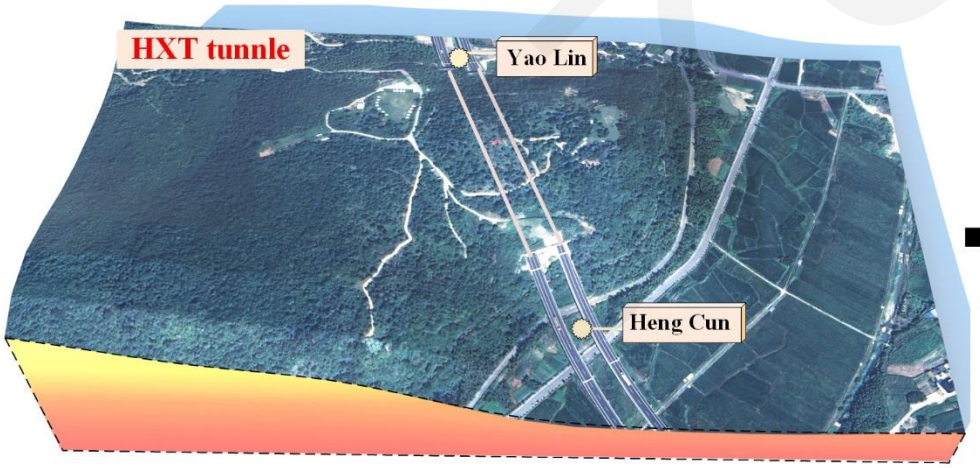
Evaluating and predicting tunnel overbreak by integrating cloud modeling and fuzzy evaluation theory

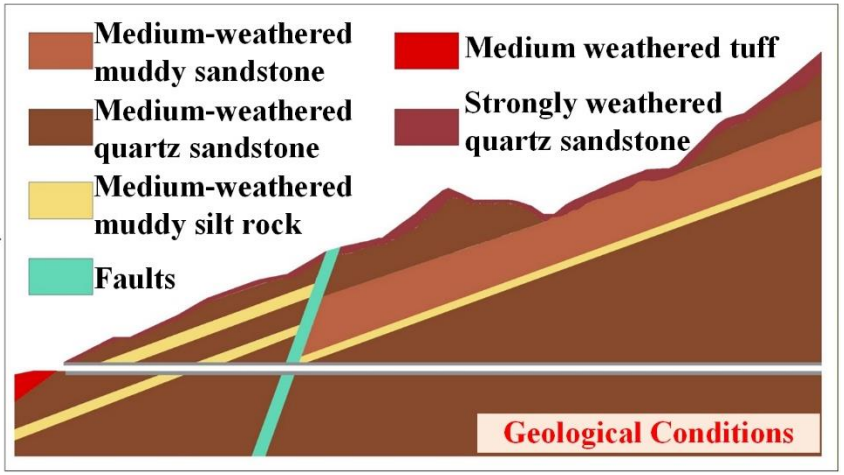
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Cite this as: Shibin YAO, Jian ZHOU, Biao HE, Chuanqi LI, 2026. Evaluating and predicting tunnel overbreak by integrating cloud modeling and fuzzy evaluation theory. *Journal of Zhejiang University-SCIENCE A*, 27(10):1153-1168. https://doi.org/10.1631/jzus.A2500581

Research background and dataset

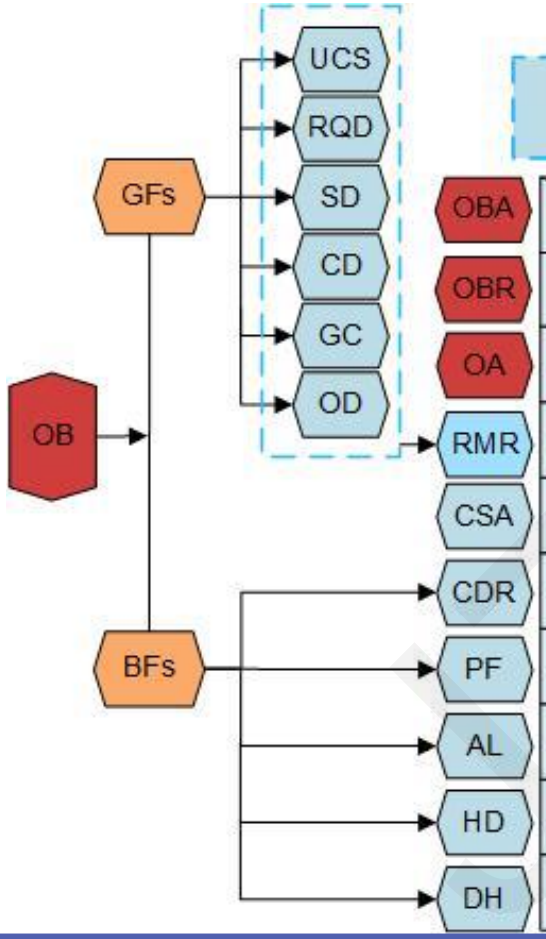
- Overbreak is a common but unfavorable phenomenon in drill-and-blast excavation.
- It increases construction cost, delays schedules, and may threaten surrounding rock stability and safety.
- This study aims to build an interpretable framework for overbreak risk evaluation and quantitative prediction.
- **Dataset: 523** excavation records from the **HuXiTai (HXT)** tunnel.
- **Inputs:** RMR, CSA, CDR, PF, AL, HD, and DH.





Indicators and grading criteria

- **Seven geological and blasting indicators were selected for overbreak assessment.**



GFs (geological factors)
BFs (blasting factors)

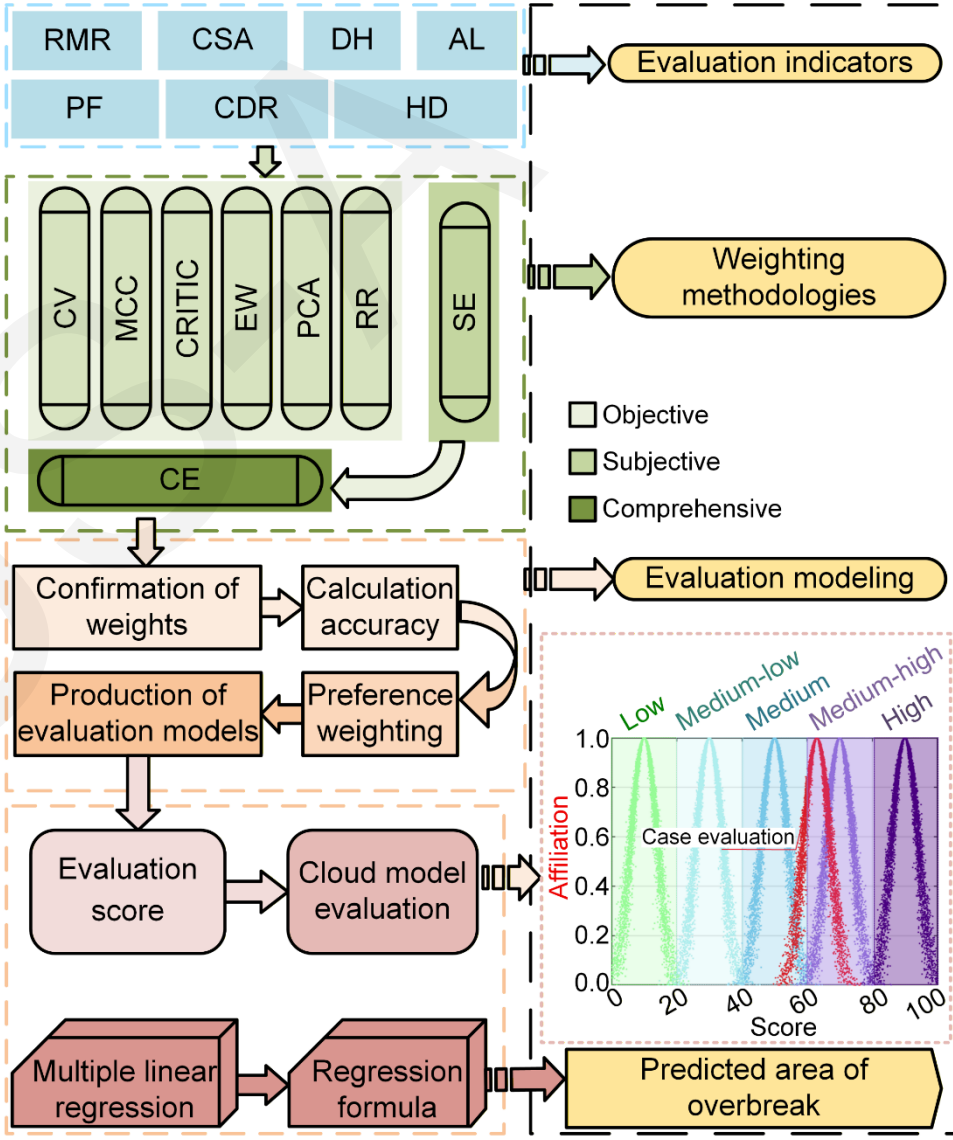
OBA (overbreak assessment)
OBR (overbreak risk)

OBA	Score / Unit	0–20	20–40	40–60	60–80	80–100
OBR	/	Low	Mediun-low	Medium	Medium-high	High
OA	m^2	<1.45	1.45–3.05	3.05–3.75	3.75–5.35	>5.35
RMR	/	<21	21–40	41–60	61–80	81–100
CSA	m^2	>81	68–81	65–68	62–65	<62
CDR	kg/m	<0.02	0.02–0.09	0.09–0.14	0.14–0.21	>0.21
PF	kg/m^3	<0.25	0.25–0.75	0.75–1.00	1.0–1.5	>1.5
AL	m	<0.5	0.5–2.3	2.3–3.1	3.1–4.9	>4.9
HD	m^{-2}	<0.6	0.6–1.7	1.7–1.9	1.9–3.0	>3.0
DH	m	<1.45	1.45–3.05	3.05–3.75	3.75–5.35	>5.35

Five risk grades from low to high underpin the subsequent evaluation and prediction.

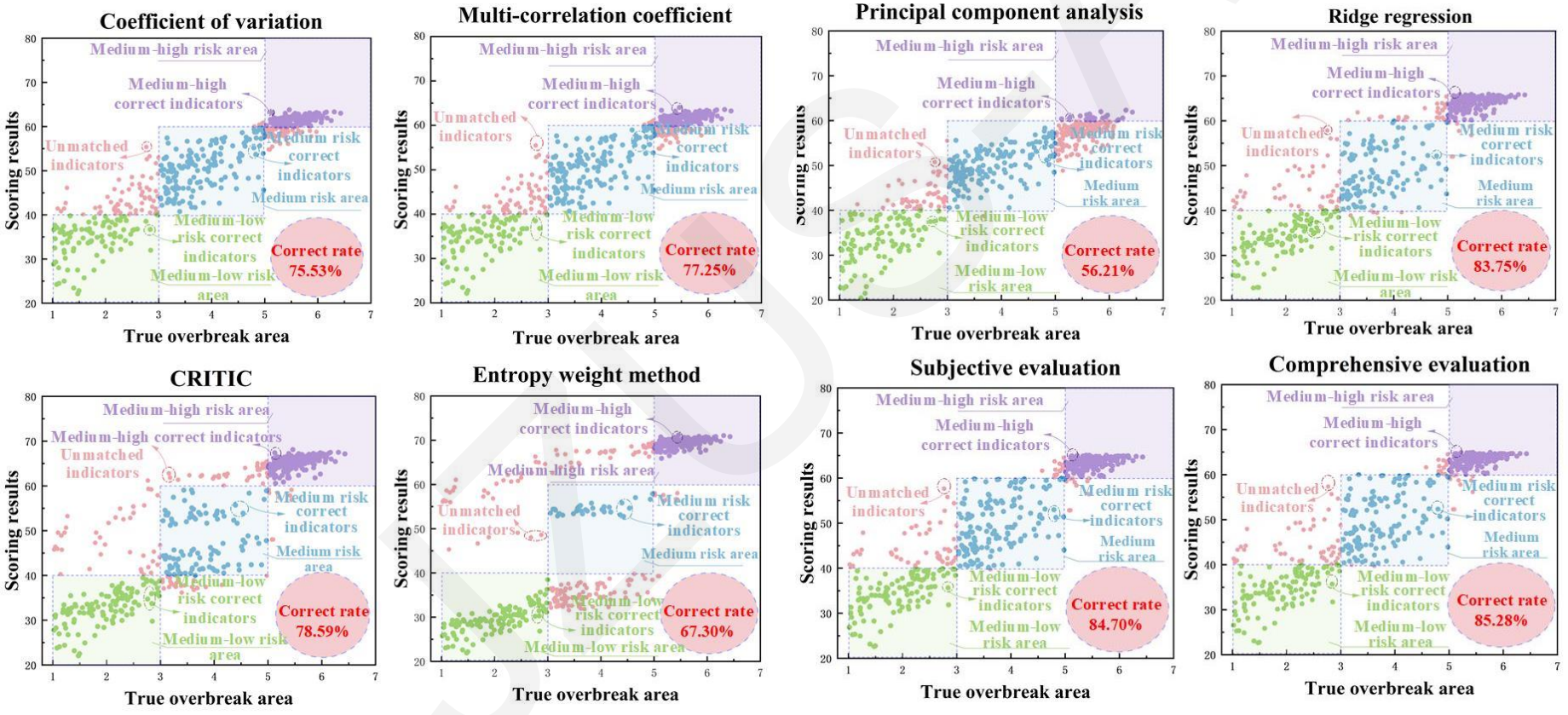
Cloud-model evaluation framework

- **Grade the original geological and blasting indicators.** Normalize and classify indicators into evaluation grades.
- **Compare multiple weighting methods,** including objective and subjective strategies.
- **Calculate the comprehensive evaluation (CE) score.** Aggregate weighted indicators to obtain the CE score.
- **Use cloud modeling to visualize overbreak risk grades** and transitional characteristics.
- Build a regression relationship for quantitative prediction of overbreak area.



Comparison of weighting methods

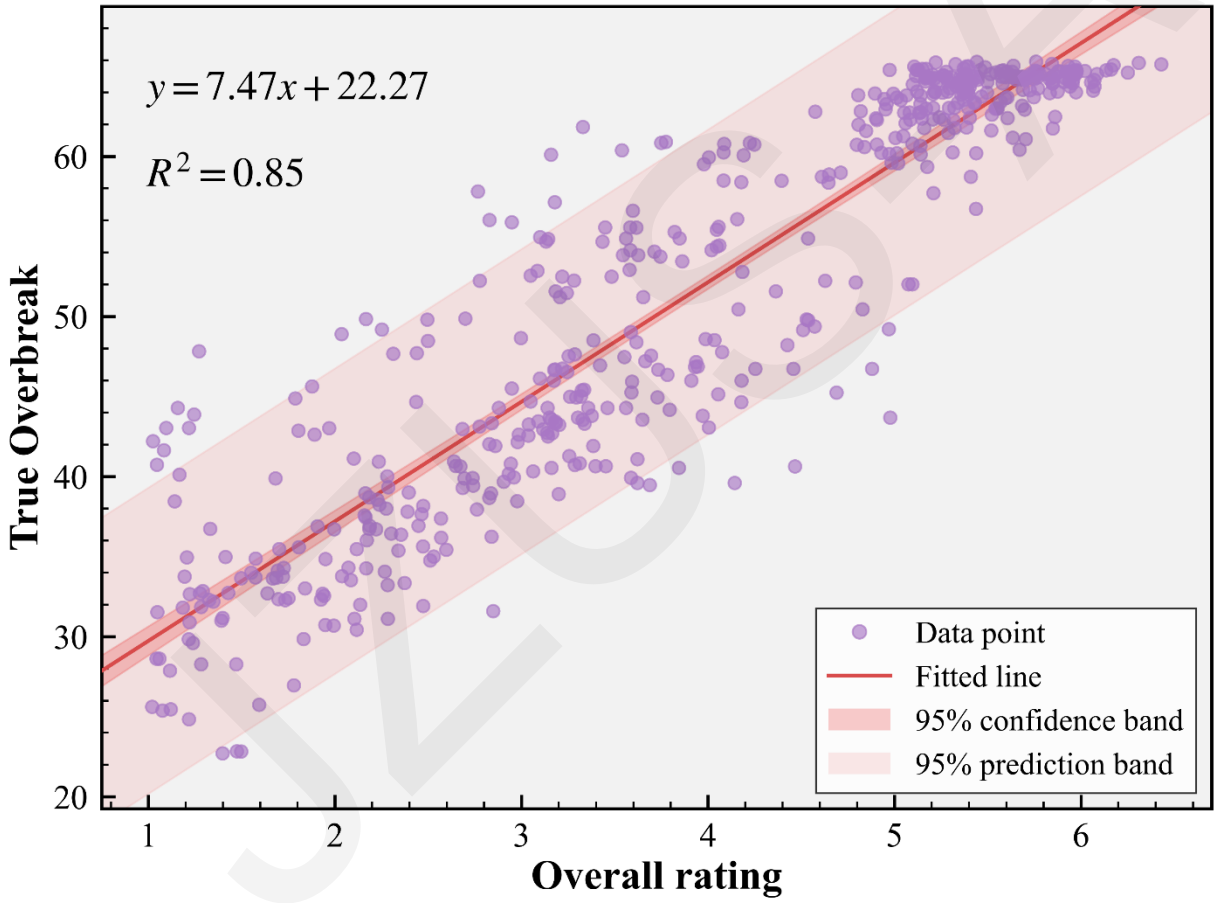
- **CE achieved the best overall performance, whereas PCA showed the lowest accuracy.**



Best: CE = 85.28%; Lowest: PCA = 56.21%

Overbreak area prediction

The CE score shows a clear positive linear relationship with true overbreak(R^2 = 0.85).



Prediction equation:

y = 7.47x + 22.27

The proposed framework provides an interpretable tool for tunnel overbreak evaluation and prediction.

Conclusions

- A cloud-model-based framework was developed for evaluating and predicting tunnel overbreak risk.
- The CE model achieved the best evaluation results, with an accuracy of 85.28%.
- The cloud model effectively visualized the uncertainty and transition characteristics near risk-grade boundaries.
- The CE score showed a clear linear relationship with the actual overbreak amount, with an R^2 value of 0.85.

The proposed framework serves as an interpretable tool for assessing overbreak risks and making quantitative predictions.