Supplementary Materials

The supplementary materials provide supporting documentation and statistical details for the documentary-importance assessment and interpretive-gap analysis described in Section 3.7. Table S1 presents the documentary evidence mapping for the twelve bridge–gene evaluation units, including the corresponding sources and interpretation boundaries. Table S2 reports the five-rater scoring matrix, normalized documentary-importance scores, model-derived UGC visibility rates, and corresponding interpretive gaps. Table S3 provides the analysis of variance (ANOVA) components and intraclass correlation coefficient (ICC) estimates used to assess inter-rater agreement. Together, these materials support the transparency and reproducibility of the documentary-importance assessment.

Supplementary Table S1 Documentary Evidence Mapping for Cultural Genes

Documentary mapping of twelve bridge–gene units. Source identifiers are explained in the source register below.

Item	Case	Cultural gene	Documentary correspondence	Source IDs	Scope / interpretation limit
WG1	Wuhan	G1 Structure–Technology	Two-level steel-truss crossing; structural system and drilled tubular-column foundations.	W01 [52], W02 [53]	Engineering description; no formal numerical G1 score.
WG2	Wuhan	G2 Materials–Craftsmanship	Steel-truss materials, rivet-fitting/assembly information, and documented subsequent bridgehead restoration.	W02 [53], W03 [54], W05 [56]	Distinguish original workmanship from later maintenance.
WG3	Wuhan	G3 Transportation–Function	Upper road deck, lower railway, and Yangtze crossing linking transport corridors.	W01 [52], W02 [53], W06 [57]	Documented function; not a measured public preference.
WG4	Wuhan	G4 History–Memory	Construction history (1950s), technical cooperation, project participants and historical commemoration.	A05 [5], W03 [54], W06 [57]	Documented history; not a direct test of public memory.
WG5	Wuhan	G5 Commemoration–Symbolism	City-landmark status, commemorative references and civic symbolism in institutional accounts.	W01 [52], W04 [55]	Public symbolism is an interpretation of documented evidence.

WG6	Wuhan	G6 Landscape–Place	Bridge–Yangtze–city relationship; Wuchang/Hanyang riverbanks and nearby hills.	W01 [52], W02 [53], W05 [56]	Place/setting evidence; no separate adopted value rating.
FG1	Forth Bridge	G1 Structure–Technology	Large steel cantilever bridge and structural engineering significance in adopted OUV and technical records.	A06 [6], F01 [58], F02 [59]	Adopted OUV supports the subject, not a numerical G1 rating.
FG2	Forth Bridge	G2 Materials–Craftsmanship	Mild-steel use, riveting, stone foundations, and later conservation/refurbishment.	F01 [58], F02 [59], F06 [63]	Do not merge nineteenth-century construction and recent restoration.
FG3	Forth Bridge	G3 Transportation–Function	Continuing rail operation and connection between Edinburgh and Fife.	F01 [58], F02 [59]	Transport function in institutional/OUV narratives.
FG4	Forth Bridge	G4 History–Memory	Historical construction, workforce, archive narratives and the 1890 opening.	F01 [58], F03 [60], F04 [61],	Nomination histories are not independent UNESCO inscription criteria.
FG5	Forth Bridge	G5 Commemoration–Symbolism	World Heritage recognition and engineering/industrial symbolic significance.	F01 [58], F02 [59]	Recognition does not constitute an official G5 importance score.
FG6	Forth Bridge	G6 Landscape–Place	Firth of Forth estuary, shoreline, settings and important views.	F01 [58], F05 [62]	Site setting is relevant without being a separate OUV criterion.

S1 Source Register (not a separate table)

A05： [5] **Yao, L. · Transnational Co-Production of Technology: Sino-Soviet Cooperation in the Construction of the Wuhan Yangtze River Bridge, 1950–1957 (2024).**

A06： [6] **Sooman, D.; Andrew, J. · Forth Bridge: The Restoration Challenge (2015).**

W01: [52]**Wuhan Municipal People's Government. Wuhan Yangtze River Bridge. Available online: https://english.wuhan.gov.cn/bridge/wuhanyangtze/index.shtml (accessed on 19 October 2026).**

W02: [53] **Hubei Provincial Department of Culture and Tourism. The Wuhan Yangtze River Bridge Standing Tall. 2014. Available online: https://wlt.hubei.gov.cn/bmdt/ztzl/zshb/201912/t20191226_1799521.shtml (accessed on 19 October 2026). (In Chinese).**

W03： [54] **Changjiang Daily. A "Signature Silk" Signed by Hundreds Displayed at the Bridge Museum, Recreating the Opening of the Wuhan Yangtze River Bridge. 2025. Available online: https://www.wuhan.gov.cn/sy/whyw/202510/t20251015_2660669.shtml (accessed on 19 October 2026). (In Chinese).**

W04： [55] **Yang, Y. The Yangtze River Bridge as a City Symbol. 2019. Available online: https://fgw.wuhan.gov.cn/xwzx/mtgz/202001/t20200116_864888.html (accessed on 19 October 2026). (In Chinese).**

W05： [56] **Changjiang Daily. First Restoration since Construction: Wuhan Yangtze River Bridge Towers to Be Restored to Their Orig-inal Appearance. 2022. Available online: https://www.wuhan.gov.cn/sy/whyw/202212/t20221212_2114209.shtml (accessed on 19 October 2026). (In Chinese).**

W06： [57] **Zhou, Z. Remembering the Transformation of the Yangtze Crossing. 2019. Available online: https://www.ndrc.gov.cn/xwdt/gdzt/cl70zn/201909/t20190930_1197745_ext.html (accessed on 19 October 2026). (In Chinese).**

F01： [58] **UNESCO World Heritage Committee. Decision 39 COM 8B.33: The Forth Bridge, United Kingdom. 2015. Available online: https://whc.unesco.org/en/decisions/6383 (accessed on 19 October 2026).**

F02： [59] **Historic Environment Scotland. The Forth Bridge. Available online: https://www.historicenvironment.scot/protect-and-care/protected-historic-places/world-heritage-sites/the-forth-bridge/ (accessed on 19 October 2026).**

F03： [60] **Forth Bridges Forum. The Forth Bridge: Nomination for Inclusion in the World Heritage List. 2014. Available online: https://www.theforthbridges.org/media/rvrb40ql/forth-bridge-world-heritage-nomination-document.pdf (accessed on 19 October 2026).**

F04： [61]**. Forth Bridges Forum. Building the Forth Bridge. Available online: https://www.theforthbridges.org/about-the-forth-bridges/forth-bridge/forth-bridge-history/building-the-forth-bridge/ (accessed on 19 October 2026).**

F05： [62] **Forth Bridges Forum. The Forth Bridge: Management Plan 2014–2019. 2014. Available online: https://www.theforthbridges.org/media/wb4n15vs/forth-bridge-world-heritage-nomination-management-plan.pdf (ac-cessed on 19 October 2026).**

F06: [63]**Historic Environment Scotland. Forth Bridge (LB40370). Available online: https://portal.historicenvironment.scot/apex/f?p=1505:300:::::VIEWTYPE,VIEWREF:designation,LB40370 (accessed on 19 Oc-tober 2026).**

Note. The references in the material have all been incorporated into the main text.

Supplementary Table S2 Documentary-Importance Rating Matrix and Revised Explanatory Gaps

Rating unit: 12 bridge–gene items; E1–E5 are five supplied numeric columns on a 0–100 scale. Anchors: 0=no documentary support; 25=incidental/indirect evidence; 50=explicitly documented; 75=important attribute with clear evidence; 100=core attribute with strong evidence. Intermediate integer scores are permitted.

Calculation: $O_(b,g) = (E1 + E2 + E3 + E4 + E5)/500$; $V_(b,g)$ is the M3 positive detection rate in Section 4.3; $Gap = O_g - V_g$

Item	Cultural gene	S1 sources	E1	E2	E3	E4	E5	O_g	V_g	Gap
WG1	G1 Structure–Technology	W01, W02	94	88	96	93	91	0.924	0.785	0.139
WG2	G2 Materials–Craftsmanship	W02, W03, W05	76	82	68	74	80	0.760	0.612	0.148
WG3	G3 Transportation–Function	W01, W02, W06	86	91	82	88	89	0.872	0.698	0.174
WG4	G4 History–Memory	W03, W06, [5]	88	79	94	90	85	0.872	0.421	0.451
WG5	G5 Commemoration–Symbolism	W01, W04	75	84	78	83	72	0.784	0.654	0.130
WG6	G6 Landscape–Place	W01, W02, W05	72	78	70	76	81	0.754	0.723	0.031
FG1	G1 Structure–Technology	F01, F02, [6]	96	93	98	97	95	0.958	0.812	0.146
FG2	G2 Materials–Craftsmanship	F01, F02, F06, [6]	90	84	88	94	82	0.876	0.741	0.135
FG3	G3 Transportation–Function	F01, F02	85	89	80	86	91	0.862	0.674	0.188
FG4	G4 History–Memory	F03, F04, F01	78	85	74	81	88	0.812	0.356	0.456
FG5	G5 Commemoration–Symbolism	F01, F02	81	87	78	85	80	0.822	0.693	0.129
FG6	G6 Landscape–Place	F01, F05	82	91	77	85	83	0.836	0.768	0.068

Supplementary Table S3 Inter-Rater Agreement (ANOVA and ICC)

Inputs and model: 12 targets (n=12), five score columns (k=5), no missing values; two-way random-effects, absolute-agreement ICC. These calculations use the verified matrix in S2.

ANOVA components

Source	df	Sum of squares (SS)	Mean square (MS)	Meaning
Bridge–gene item (between targets)	11	2131.933333	193.812121	—
Rater column (between raters)	4	141.733333	35.433333	—
Residual/error	44	831.066667	18.887879	—
Total	59	3104.733333	—	—

ICC estimates and 95% confidence intervals

Statistic	ICC estimate	Lower 95% CI	Upper 95% CI	Interpretation
ICC(A,1): single measures	0.633	0.394	0.849	Agreement of one score column
ICC(A,5): five-column average	0.896	0.765	0.966	Agreement of mean score used for O_g

Formulae:$ICC(A,1) = (MS_target - MS_error)/[MS_target + (k-1)MS_error + k(MS_rater - MS_error)/n]$;$ICC(A,k) = (MS_target - MS_error)/[MS_target + (MS_rater - MS_error)/n]$. The 95% confidence limits use an F-distribution-based procedure; $n = 12,\ k = 5$.

Results: ICC(A,1)=0.633 (95% CI 0.394–0.849); ICC(A,5)=0.896 (95% CI 0.765–0.966).