SUPPLEMENT_S2: ARP specification and expert protocol (retrospective application)

S2.1. Lifecycle terms and age-position function

We define L_p (notional physical life), L_b (elapsed life), and L_u (remaining useful life). We report $EL_b = L_b/L_p$ and $EL_u = L_u/L_p$ (fractions in [0–1]). In this retrospective setting, EL_u is estimated independently to reflect renewal from past interventions; therefore $EL_b + EL_u \neq 100\%$.

Age-position function $f(EL_u, EL_b)$ follows the heritage-adapted Langston specification (see Eq. (3) in the main text), with the maximum near $EL_u \approx EL_b$. Where applicable (e.g., phases P4–P5), lifecycle terms and the age-position function $f(EL_u, EL_b)$ were computed separately for the historic corpus (1930 wing) and the 2009 wing, using distinct lifecycle parameter sets; phase-level reporting follows the combined decision scope when both wings exist (see S1 Codebook: GO/Decision reported on OW+NW).

S2.2. Lifecycle policy Lp with partial resets

Baseline Lp was defined as 120 years for the 1930 corpus. During major modernisation phases, partial lifecycle renewals were considered in proportion to the share of the structure reconstructed or newly built, producing separate lifecycle trajectories for the historic corpus (SS, 1930) and the new wing (NS, 2009). The 2009 wing therefore employs a distinct parameter set reflecting its later construction date.

For each modernisation phase, L_b (elapsed life) and L_u (remaining useful life) were recalculated relative to the appropriate L_p to account for renewal effects and the extended useful life. This approach avoids a full "reset" of life expectancy while recognising significant interventions. All lifecycle parameters, phase definitions, and decision windows are provided in the computation template workbook, sheet CONFIG_PHASES; Supplementary File S1 stores final aggregated phase-level values (no embedded formulas). Decision windows follow the main text: ±3 years for early phases (P1–P2) and ±2 years for later phases (P3–P5). The rationale for renewal shares and lifecycle adjustments is documented by sources listed in Appendix A.

S2.3. Obsolescence factors O1–O7: questionnaire and within-factor aggregation

Seven factors (physical, economic, functional, technological, social, legal, political) were operationalised via a structured expert questionnaire. Items were rated on {0, 0.5, 1}. Within a factor i, items j have weights wj (which are renormalised after excluding N/A). The factor score O_i for each phase represents the weighted mean of available items after renormalization.

Table S2-2. O-factor questionnaire (excerpt; full item bank and weights are provided in the computation template workbook (sheet ITEMS); S1 reports aggregated factor results).

Factor	Item no	Item	Weight
O1 — Physical	O1_1	Does the structural condition ensure long-term durability?	2
O1 — Physical	O1_2	Do floor slabs and vertical circulation cores provide sufficient load-bearing capacity and stability?	2

O1 — Physical	O1_3	Are roofs, façades, and waterproofing systems in good condition?	1
O1 — Physical	O1_4	Does the structure have reserve capacity for future loads?	2
O1 — Physical	O1_5	Are there deformations or settlements affecting usability?	1
O1 — Physical	O1_6	Are internal partitions easy to dismantle or modify?	1
O1 — Physical	O1_7	Is technical and diagnostic documentation (BIM/as-built) available and reliable?	1
O2 — Economic	O2_1	Is the ratio of adaptation cost to new construction cost favorable?	2
O2 — Economic	O2_2	Does the profitability of the building after adaptation meet local benchmarks?	2
O2 — Economic	O2_3	Are vacancy risks and demand absorption at an acceptable level?	1

Note: Table truncated for brevity. See the computation template workbook (sheet ITEMS) for the complete O1–O7 item bank and weights; S1 contains the aggregated outputs only.

S2.4. N/A renormalisation and examples

Procedure:

- If an item is marked N/A, exclude it from aggregation.
- Renormalise remaining item weights so that their sum equals 1.
- Compute the weighted mean using the renormalised weights.

Worked example:

Assume a factor with three items (weights 0.4, 0.3, 0.3) and scores (1, 0.5, N/A). Excluding the N/A item, renormalise weights → (0.4/0.7, 0.3/0.7) = (0.571, 0.429). Factor score = 0.571·1 + 0.429·0.5 = 0.786.

Edge case: If all items in a factor are N/A for a phase, the factor is not computed for that phase (no imputation); the phase-level aggregation uses only available factors. Between-factor weights are equal across O1–O7 and are renormalised to sum to 1 when fewer than seven factors are available for a phase.

S2.5. Between-factor aggregation and ARP

Between-factor aggregation follows Eq. (2) in the main text, using equal weights across the seven dimensions (O_1–O_7).

Adaptive Reuse Potential (ARP) is computed according to Eq. (3) in the main text, which combines the age-position function $f(EL_u, EL_b)$ with the aggregated obsolescence index ΣO.

For reproducibility, the logical structure of the spreadsheet calculations used in the computation template workbook is outlined below. All computations used phase-level median values of ΣO

(across raters) and deterministic f(EL_u, EL_b), ensuring internal consistency between expert ratings (O-factors) and lifecycle analysis (AGE_POSITION sheet in the template).

Calculation workflow (logical references):
• R (stored in S1 as R_Readiness) is computed as 0.25·F + 0.25·G + 0.20·U + 0.20·D + 0.10·P (see S3; component inputs are organized in the READINESS_FP sheet of the template).
• ARP [%] is derived from the sheet AGE_POSITION (template; separate parameterization for P4–P5 wings), representing the value of f(ELu, ELb) combined with ΣO as per Eq. (3) in the main text.
• GO is computed as (ARP_%/100) × R and reported as GO [%] where denoted [%], providing the composite decision metric (WAIT / PREPARE / GO).

Unit convention: computationally, GO is stored as a fraction in [0–1]; decision thresholds are applied to the fraction (WAIT < 0.20; PREPARE 0.20–0.35; GO ≥ 0.35), and GO is displayed as percent where denoted [%].

Wing-combination reporting rule: When both wings exist (P4–P5), GO and the final decision are reported only for the combined (OW+NW) scope; wing rows may retain lifecycle and O-factor context (see S1 Codebook).

Worked macro-example (phase P3): ARP = 61.64%; R = 0.75 ⇒ GO = 0.6164 × 0.75 = 0.4623 ⇒ 46.23% (decision per thresholds in the main text/S3).

S2.6. Expert panel and rating protocol (anonymised)

The expert assessment was conducted in a retrospective, document-supported mode, using the structured questionnaire described in Section S2.3. For each phase, the obsolescence factors (O_1–O_7) were rated independently by a panel of three to four domain experts: typically two conservation architects, one architect, and, in the most recent phases (P4–P5), an additional facility manager — all directly involved in the study and, at different points, in the Renoma adaptation projects.

Individual scoring was performed using the predefined prompts, and consensus values were derived as medians across the three or four raters. Dispersion was expressed as the interquartile range (IQR). Earlier historical phases were qualitatively assessed with lower reliability, given the longer temporal distance and limited availability of primary evidence. Individual ratings are not reported in Supplementary Materials; only aggregated (median and IQR) values are provided to preserve clarity and anonymity, as well as to avoid redundancy with the phase-level summaries presented in the main text.

Supplementary consultations were held with the project's structural engineer and architects responsible for subsequent refurbishment phases; these participants did not complete rating forms but contributed to the validation and calibration of factor-level interpretations. All expert ratings were cross-verified against archival and project documentation compiled in

Appendix A, ensuring traceability of evidence and consistency between expert judgment and historical sources.

Ethics and anonymity: All participants provided informed consent; personal data were anonymised, and no sensitive information was collected. The study was conducted in accordance with institutional research ethics guidelines.

Data reporting: Aggregated results (medians, quartiles Q1–Q3, IQR) by factor and phase are presented in Appendix B. Supporting documentary evidence is listed in Appendix A, and the complete phase-level dataset of final aggregated values is available in Supplementary File S1 (xlsx); working sheets (items/weights, lifecycle configuration) reside in the computation template workbook.

S2.7. Data files and replication map

Equations (1)–(3) from the main text are implemented in the computation template workbook, which, together with S1, supports the complete phase-level dataset used for computation of EL_b, EL_u, ΣO, ARP, and GO values. The workbook (template) includes four core sheets, corresponding to the analytical stages of the study (lifecycle parameters, expert questionnaire, readiness assessment, and integrated results).

The table below summarises their purpose and key columns.

Table S2-3. Replication map: computation template workbook sheets → purpose → key columns

Sheet	Purpose	Key columns (snapshot)
CONFIG_PHASES	Phase labels and decision windows; lifecycle parameters	Assessment_Time, RefYear, Phase_Label, DecisionWindow_RefYear (±2–3 years), L_p, EL_b, EL_u
ITEMS	Questionnaire items and within-factor weights	Factor, Item no, Item, Weight
READINESS_FP	Readiness components (F–G–U–D–P) and computed index R	Assessment_Time, RefYear, F_Finance, G_Governance, U_Use, D_Delivery, P_Policy, R_Readiness [optional: notes/evidence; GO [%] and Decision in (P, OW) for P1–P3 and in (P, OW+NW) for P4–P5]
GO_SUMMARY_new	Summary of ARP, Readiness R and final GO decision	Assessment_Time, RefYear, ARP [%], Readiness_R, GO [%] (=ARP×R), Decision (WAIT/PREPARE/GO)

Note: S1 contains the final aggregated phase-level values (no embedded formulas). The computation template workbook holds the working sheets and formula logic that generate S1; together they provide full traceability and replication of the results reported in the main text.