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Development of Quality Performance Index for Quality Evaluation of High-End Residential Projects

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ABSTRACT

High-end residential construction requires a quality evaluation approach that can combine physical technical quality, managerial process quality, and user perception in a single, traceable measure. This study reports a cross-sectional, single-project pilot study that developed a preliminary Quality Performance Index (QPI) as a project-specific diagnostic tool for the construction implementation stage. A mixed methods case study was applied to the Widya Chandra Residence Project in Jakarta. Five main criteria and 25 subcriteria were compiled from a structured literature review and construction-quality practice, then validated by seven experts through focused discussion before being used in the Analytic Hierarchy Process (AHP); the same seven experts subsequently supplied pairwise-comparison judgments used to derive criterion and subcriterion weights. Actual performance was rated by 47 project stakeholders using a 1-5 Likert scale. Item-total correlations of the instrument ranged from 0.388 to 0.845, above the r-table value of 0.288, and Cronbach's Alpha reached 0.955; these results indicate acceptable item discrimination and high internal-consistency reliability, but they are not by themselves evidence of content or construct validity, which were not separately tested in this study. AHP results placed Technical Quality of Construction Work at 31.7%, Perception and Satisfaction of Users/Owners at 27.1%, Material Quality at 16.7%, Quality Management System at 12.6%, and Implementation and Control Process at 12.0%. Because these rounded weights summed to 1.001, they were normalized before being multiplied by the actual scores; the resulting Quality Performance Index is 4.212, which falls in the Excellent band of a corrected four-band rating scale (Excellent, Good, Fair, Poor) spanning the 1-5 measurement range. The QPI framework is proposed as a preliminary internal diagnostic tool for periodic evaluation and identification of improvement priorities on a single project; benchmarking across different high-end residential projects is not yet supported and requires calibration on independent samples.

Keywords: *Analytic Hierarchy Process, high-end residential, quality performance, construction management, Quality Performance Index*

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INTRODUCTION

Measuring the success of construction projects is evolving from traditional approaches that emphasize cost, time, and quality toward more multidimensional systems. Performance evaluation at the project level needs to include non-financial indicators so that success can be assessed more fully, including stakeholder satisfaction, safety, technology, environment, and project value [1], [2].

In this study, a high-end residential project is operationally defined as a private housing development characterized by custom architectural design, premium finishing materials, integrated structural-architectural-MEP work, and a client relationship in which the owner directly specifies and inspects quality outcomes rather than relying only on standard developer specifications. The Widya Chandra Residence Project was selected as the case because it exhibits all four characteristics and because its project team granted access to inspection records, quality-control documents, and both expert and stakeholder respondents, which made an in-depth single-case pilot feasible. In such projects, quality is judged not only by technical compliance, but also by the comfort and acceptance of the user in relation to the final result of the building [3].

Quality control practices in the field generally use inspection checklists, Non-Conformance Reports (NCR), defect lists, test reports, and progress documents [1], [2], [3]. These instruments are important, but they remain separate and do not always produce a single composite measure that can demonstrate quality performance concisely. ISO 9001:2015 emphasizes a process approach, customer focus, performance evaluation, non-conformity control, and continuous improvement [4]. The implementation of a quality management system in construction projects also demonstrates the importance of documentation, consistency of procedures, and performance evaluation to support quality achievement [5].

This study uses multidimensional quality performance to mean the combination of technical, material, managerial, process, and user-perception outcomes at the construction implementation stage. It does not claim to represent overall project success in the broader sense used elsewhere in the literature: cost, schedule, occupational safety and health, environmental performance, and post-occupancy outcomes are explicitly outside the scope of the index and are not implied by the term 'quality' as used here.

A number of previous studies have become the conceptual basis for the development of the index. Nassar combines several project performance objectives using AHP [6]. Shaawat et al. developed the Performance Quality Index (PQI) to assess contractors' professional behavior on sustainable construction projects [7], while Leong et al. showed the relationship between Quality Management System (QMS) practices and project performance [8]. The composite index approach is also considered effective in bringing together various performance indicators into a single comparable score [9]. However, prior studies have not produced a quality index for high-end residential projects in Indonesia that jointly traces technical quality, materials, quality management systems, implementation and control processes, and user perception down to the indicator level within one weighted, auditable model.

Beyond combining Total Quality Management (TQM), a Quality Management System (QMS), Key Performance Indicators (KPI), AHP, and a weighted-sum index, the contribution claimed here is the specific five-criterion, 25-subcriterion hierarchy built for the construction-implementation stage of high-end residential work, together with an explicit, auditable weighting-and-scoring procedure that keeps every composite value traceable back to its criterion and subcriterion origin [4], [5], [6], [7]. TQM emphasizes leadership commitment, organizational engagement, customer focus, process control, and continuous improvement [10]. Quality is shaped through the quality of processes, organizations, and products [11], so modern control needs to emphasize the prevention of non-conformities, defects, and rework, not just final inspections [12]. KPIs translate strategic objectives into actionable measures; in construction projects, performance indicators can include cost, time, quality, safety, productivity, stakeholder satisfaction, technology, and the environment [1], [13]. In this study, QPI is positioned as a composite indicator that specifically focuses on quality performance and breaks it down into technical, material, managerial, process, and user indicators [14].

Indicator development process

The five criteria and 25 subcriteria were developed in three stages: (1) a structured review of construction-quality literature and standards, including TQM, QMS, KPI, and post-occupancy evaluation sources; (2) mapping of recurring themes from that review against field practice documents (inspection checklists, NCR formats, and quality plans) from the case project; and (3) a validation round in which the seven experts reviewed, merged, or removed candidate items before the final 5-criterion, 25-subcriterion hierarchy was fixed for AHP weighting. Table 1 summarizes the theoretical basis of each main criterion [8], [9], [10].

Table 1. Theoretical basis of the five main QPI criteria

Code	Main criterion	Primary theoretical basis
A	Technical quality of construction work	TQM process control; prevention of non-conformity, defects, and rework [10]-[12]
B	Material quality	Specification conformity and material certification practice [11]
C	Quality management system	ISO 9001:2015 process approach and quality planning [4], [19]
D	Implementation and control process	KPI-based process and productivity control [1], [13]
E	User/owner perception and satisfaction	Post-occupancy and user-acceptance evaluation [3]

The AHP is used to determine the relative priority of each criterion and subcriterion through paired comparisons and consistency testing [15].

The composite QPI score is bounded by the 1-5 Likert range used for the actual-performance ratings, so the rating scale is corrected here to four ordinal bands: Rank-1 (Excellent) for $4 \le X \le 5$, Rank-2 (Good) for $3 \le X < 4$, Rank-3 (Fair) for $2 \le X < 3$, and Rank-4 (Poor) for $1 \le X < 2$. The original five-band scheme included an unreachable $0 \le X < 1$ category and duplicated the 'Good' label for two adjacent bands; both issues are corrected in this revision [16].

Research questions

This study addresses four research questions: (RQ1) which quality criteria and subcriteria are relevant for evaluating high-end residential construction quality, (RQ2) what relative priority weight does each criterion and subcriterion receive from expert judgment, (RQ3) what is the actual performance level of the case project on each criterion, and (RQ4) how do weight and actual performance combine into a single, interpretable QPI value, and with what limitations on its use [11], [12].

Based on these gaps, this study aims to formulate relevant quality criteria and sub-criteria, determine priority weights using AHP, measure actual performance, and form a QPI model for the construction implementation stage [13], [14], [15], [16]. The study was limited to high-end residential projects during construction with quantitative, measurable, and verifiable indicators. Aspects of cost, occupational safety and health, and the environment are not included in the formation of the index.
The contribution of this study is limited to a preliminary, project-specific evaluation tool piloted on a single case; it is not yet a generally applicable Jakarta high-end residential benchmarking index. Its novelty lies in integrating five quality dimensions into one composite index that remains traceable to the indicator level and can complement inspections, periodic evaluations, and future benchmarking once validated on independent projects.

MATERIAL AND METHOD

This is a cross-sectional, single-case mixed methods study; the design does not include repeated measurement over time and does not, by itself, support generalization beyond the case project. The research uses a mixed methods approach with a case study design on the Widya Chandra Residence Project, Jakarta. Qualitative data was obtained through literature review, interviews, observations, and project document review, while quantitative data was obtained from AHP weighting and actual performance assessment. The integration of the two approaches is used to obtain measurable results that remain representative of field conditions [17].

Because the qualitative component (interviews, observation, and document review) is reported at a summary level rather than with a fully reproducible protocol, it is best read as a supporting, non-reproducible input to indicator development and document triangulation rather than as an independent qualitative strand with its own research questions, coding scheme, and trustworthiness checks [17].

Respondents were divided into two groups. The first group consisted of seven experts, academics and practitioners who provided validation and pair-based comparative assessments. The second group consists of 47 stakeholders directly involved in the project, including owners, consultants, contractors, subcontractors, and suppliers. The second group assessed 25 subcriteria using a Likert scale of 1-5. The selection of respondents was carried out purposively based on experience and involvement in project quality control [18].

Contractor, subcontractor, and supplier respondents rated criterion E items as their perception of user/owner satisfaction with the delivered work rather than as user satisfaction itself; this internal-stakeholder perspective is a proxy and may differ from the owner's or occupant's own post-occupancy assessment. Results for criterion E should therefore be read as perceived alignment with user expectations by project participants, and subgroup-level comparisons (owner/consultant scores versus contractor/subcontractor/supplier scores) are recommended in future analysis [19], [20].

Each expert compares the criteria and subcriteria in pairs using the Saaty scale. Individual assessments are combined with geometric means. The consistency of the matrix was tested using the Consistency Ratio (CR) and accepted when the $CR < 0.10$ [15].

Negative-direction indicators, such as the occupational-defect and rework rate under criterion A (A3), were reverse-scored before averaging so that a higher value on the 1-5 scale consistently denotes better quality performance across all subcriteria; the sign convention is stated here because it affects both the descriptive averages in Table 4 and the regression coefficients. Actual performance is calculated from the average score of respondents' assessments. QPI is then determined by the equation $QPI = \Sigma(W_i \times X_i)$, with W_i as the composite weight, X_i as the actual score, and $\Sigma W_i = 1$.

Because the AHP output is reported to three decimal places, the raw weights sum to 1.001 rather than 1.000; before use in the QPI equation, weights were normalized (each weight divided by 1.001) so that $\Sigma W_i = 1.0000$ exactly. This normalization step, and the unrounded weights it uses, are reported in Table 3 in the Results section so the QPI value is fully auditable [21], [22].

The scores discussed as 'technical quality' and 'material quality' in this study are respondents' perceived performance ratings on a 1-5 Likert scale, not independently measured objective records such as defect counts, non-conformance report tallies, or laboratory test results. Perceived and objective performance can diverge, particularly under social-desirability or common-method bias; this distinction is carried through the Results, Discussion, and Conclusion sections of this revision.

The validity of the grains was tested using Pearson correlation and the reliability of the instrument using Cronbach's Alpha. Advanced analysis includes descriptive statistics, Pearson correlation between dimensions, and multiple linear regression. The results of the questionnaire were verified with weekly reports, meeting minutes, NCR or field memos, inspection checklists, work methods, and SOPs as data triangulation. Digitization of inspections and documentation can strengthen the reliability of project quality evidence [18].

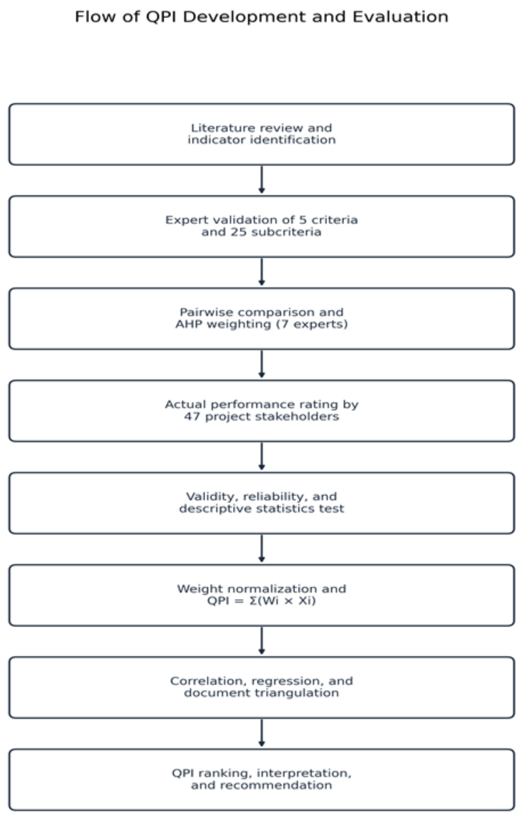

Figure 1. Flow of QPI development and evaluation

RESULTS AND DISCUSSION

Validity, Reliability, and AHP Consistency

All 25 subcriteria have an item-total correlation of 0.388-0.845, larger than the r-table value of 0.288, indicating acceptable item discrimination. Cronbach's Alpha reached 0.955, indicating very high internal consistency; an alpha this high can also indicate item redundancy among the 25 subcriteria, and it is not sufficient on its own to claim that the instrument is valid. Content validity (expert judgment that items represent the intended construct) and construct validity (evidence that items group according to the intended five-dimension structure) were not separately tested here and are recommended as follow-up analysis.

The entire paired-comparison matrix of the seven experts also met CR < 0.10, so the AHP weights were feasible to use in the QPI calculation.

Priority Weights of Main Criteria and Subcriteria

The AHP results placed the Technical Quality of Construction Work (A) as the criterion with the highest weight, followed by Perception and User/Owner Satisfaction (E), Material Quality (B), Quality Management System (C), and Implementation and Control Process (D). The first three dimensions make up about three-quarters of the model's weight. The high technical and material position is consistent with the character of the construction project, which places the suitability of specifications and the quality of physical results as the foundation for quality achievement [14].

Table 3. AHP weight (raw and normalized), actual performance, and contribution of the five main criteria

Code	Criteria	Raw AHP weight (3 dp)	Normalized weight used in QPI	Actual score (1-5)	Contribution to QPI
A	Technical quality of construction work	0.317	0.3167	4.140	1.311
B	Material quality	0.167	0.1668	4.366	0.728
C	Quality management system	0.126	0.1259	4.200	0.529
D	Implementation and control process	0.120	0.1199	4.111	0.493
E	User/owner perception and satisfaction	0.271	0.2707	4.251	1.151

Code	Criteria	Raw AHP weight (3 dp)	Normalized weight used in QPI	Actual score (1-5)	Contribution to QPI
	Total	**1.001**	**1.0000**	-	**4.212**

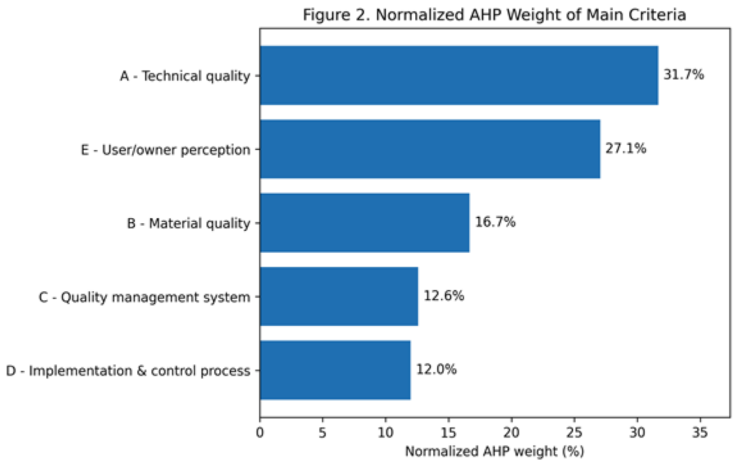

Figure 2. Normalized AHP weight of the main criteria

At the subcriterion level, A1 (conformity of implementation with design and specifications) obtained the largest global weight of 0.109. The next positions are E2 and E1 at 0.082 each, A2 at 0.062, A4 at 0.061, and B1 at 0.057. In local weight, C1 (implementation of the Project Quality Plan, PQP) obtained 0.368 and D1 (accuracy of work methods and implementation procedures) obtained 0.369. These findings show that physical results, quality planning, and accuracy of work methods need to be managed in an integrated manner. The quality plan guidelines also emphasize the need for structured planning, accountability, inspection, and quality documentation [19].

Table 4 below reports the ten subcriteria with the highest global weight, consistent with the original manuscript.

Table 4. Subcriteria with the highest global weight

Code	Subcriteria	Global weight
A1	Work conformity to design and specifications	0.109
E2	Perception of beauty and comfort	0.082
E1	Perception of the quality of implementation	0.082
A2	Dimensional and level tolerance accuracy	0.062
A4	Compliance with technical standards	0.061
B1	Suitability of materials to design and specifications	0.057
A5	Performance of the results of the implementation of the work	0.051
E3	Perception of material quality	0.048
C1	Implementation of Project Quality Plan (PQP)	0.046
D1	Accuracy of working methods and procedures	0.044

Current Project Performance

The actual score of the five criteria ranged from 4.111 to 4.366. Material Quality (B) obtained the highest score at 4.366, followed by User/Owner Perception and Satisfaction (E) at 4.251, Quality Management System (C) at 4.200, Technical Quality (A) at 4.140, and Implementation and Control Process (D) at 4.111. All scores are above 4.00, so perceived quality is generally rated very good by respondents. The difference between weight and actual score is important to note: technical quality is the highest strategic priority, while actual performance is strongest in materials.

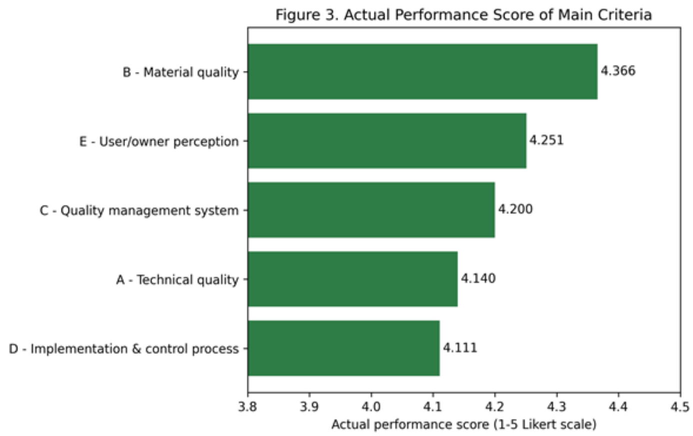

Figure 3. Actual performance score of the main criteria

At the subcriterion level, Certification and Material Quality Standards (B2) obtained the highest score of 4.468; B1 and B5 obtained 4.404 each; and material inspection and testing procedures (B4) obtained 4.383. In contrast, the defect and rework rate (A3, reverse-scored) obtained the lowest score of 3.957. These findings indicate that the material system is a strength of the project, while defect prevention and rework remain a priority for improvement. Rework needs to be managed from the point of view of contract provisions, methods, coordination, and precautions [20].

Importance-performance reading of the priorities

Reading weight and actual score together rather than separately gives a sharper priority signal than ranking alone. Technical Quality (A) combines the highest strategic weight (31.7%) with the lowest actual score among the five criteria (4.140), and its own lowest-scoring subcriterion is the defect and rework rate (A3, 3.957); this combination of high importance and comparatively weaker performance marks A3 as the most consequential single item for a corrective-action program. Material Quality (B) shows the reverse pattern: a moderate weight (16.7%) paired with the highest actual score (4.366), so it is already a relative strength that mainly needs to be maintained rather than prioritized for new investment. Implementation and Control Process (D) combines the lowest weight (12.0%) with the lowest actual score (4.111), which is a lower-urgency combination than A but still warrants monitoring given its correlation with Quality Management System performance.

Correlation and Multiple Linear Regression

The correlation between the five dimensions was all positive, in the range of 0.500-0.809. The strongest relationship was found between Quality Management System (C) and Perception and User/Owner Satisfaction (E) at r = 0.809, followed by A-C at 0.651 and C-D at 0.627. These results show the position of the quality management system as a dimension closely related to technical quality, process effectiveness, and user assessment, consistent with previous findings on the relationship between QMS and project performance [8].

A correlation of 0.809 between C and E is high enough to question whether AHP's assumption that criteria are independent at the same hierarchy level still holds for this pair. Because AHP treats sibling criteria as non-interacting, while an Analytic Network Process (ANP) explicitly models interdependence and feedback among criteria [21], [22], a useful follow-up test is to re-estimate the C and E weights using ANP and compare the resulting priorities and QPI value against the AHP-based results reported here.

The regression outcome variable, $\bar{X}$, is the simple average of the five criterion scores A-E rather than an independently measured overall-quality item. Because $\bar{X}$ is arithmetically derived from A-E, a regression of $\bar{X}$ on A-E is partly definitional: it will tend to recover coefficients related to how the average is constructed rather than an independent causal or even purely associative relationship, and the resulting R^2, coefficients, and significance values cannot be interpreted as if $\bar{X}$ were an outcome measured separately from the five predictors. This revision therefore reports the regression as a descriptive decomposition of the composite average, not as a test of which dimension drives an independent outcome, and removes any earlier suggestion that the coefficients reveal a causal ordering of importance among the criteria.

Table 5. Descriptive regression decomposition of the composite average $\bar{X}$ on criteria A-E

Criteria	B	Beta	t	Sig.	Status
A - Technical	0.047	0.035	0.558	0.580	Not significant*
B - Material	0.146	0.118	2.058	0.046	Significant*
C - Quality system	0.185	0.185	2.174	0.036	Significant*
D - Process	0.265	0.282	4.662	$p < 0.001$	Significant*
E - Users	0.422	0.500	6.414	$p < 0.001$	Significant*

QPI Value, Ranking, Verification, and Implications

Using the normalized weights in Table 3, the contribution of each criterion to the QPI is: A = 1.311, B = 0.728, C = 0.529, D = 0.493, and E = 1.151. The accumulation of all contributions results in a QPI of 4.212. Based on the corrected interval of 4 ≤ X ≤ 5, the project obtains a Rank-1, Excellent classification. These results show that the objective quality of the construction results and the quality felt by users need to be maintained at the same time.

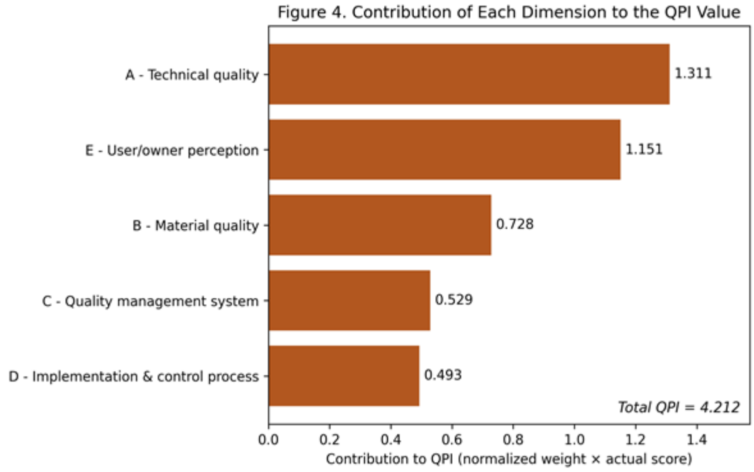

Figure 4. Contribution of each dimension to the QPI value

Because the additive model lets a strong score on one dimension offset a weak score on another, a project could in principle reach an Excellent overall QPI while still carrying an unresolved critical technical deficiency, for example an unaddressed structural, waterproofing, or fire-safety non-conformance. This risk is not fully tested in the current data, but it motivates a proposed refinement: before any project is classified as Rank-1 (Excellent), mandatory structural, waterproofing, fire-safety, and commissioning requirements should first pass a separate pass/fail gate, independent of the weighted average, so that a serious safety-critical nonconformity cannot be compensated by high scores elsewhere.

Reading Table 3 and the importance-performance analysis in Section 3.2 together, the clearest improvement priority is the defect and rework rate under Technical Quality (A3): it sits inside the highest-weighted criterion yet is the lowest-scoring subcriterion in the dataset. A concrete improvement action would assign responsibility to the site quality-control team and main contractor, use the project's NCR log and rework cost/time records as before-after evidence, and set a measurable target (for example, a defined percentage reduction in NCR count or rework hours over the next reporting period) rather than relying on the perception score alone.

Because both AHP judgments and stakeholder ratings were supplied by individuals connected to the project (including contractor and subcontractor staff rating criterion E), organizational interest may have influenced some ratings toward more favorable scores; independent or post-occupancy evidence from the owner or occupants was not collected in this pilot and would be needed to confirm whether the internal stakeholder scores, especially for E, hold up from an external vantage point.

The corrected QPI of 4.212 and the Rank-1 classification describe the Widya Chandra Residence Project at the time of data collection only; the weights, the rating thresholds, and the specific subcriteria priorities were derived from and calibrated to this single case, and they should not be assumed to transfer directly to other high-end residential projects that differ in design complexity, contractor capability, ownership structure, or quality-management maturity without re-validation.

Verification using weekly progress reports, meeting minutes, NCR or field memos, inspection checklists, work methods, and SOPs showed general conformity with respondents' assessments. The project documents show that non-conformances are recorded and acted upon through corrective actions. This triangulation supports, but does not independently confirm at a metric level, the QPI value of 4.212 and Rank-1 classification at the time of evaluation.

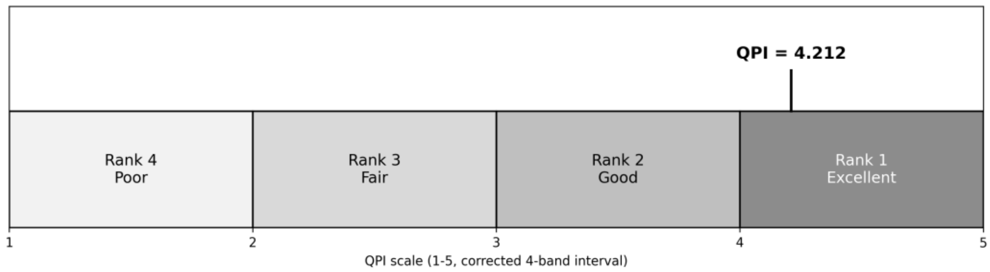

Figure 5. Position of the project's QPI value on the corrected four-band rating scale

The main novelty of this study is a QPI model designed specifically for high-end residential projects in Indonesia at the construction implementation stage. As a preliminary tool, it is best used as an internal diagnostic alongside objective quality records and user evidence, subject to the mandatory acceptance thresholds for critical technical requirements proposed above, rather than as a validated benchmarking instrument. The model integrates technical quality, material quality, quality management system performance, implementation and control processes, and user perception and satisfaction. Compared to evaluations that use only separate checklists or indicators, this approach produces a single index that remains traceable to the level of criteria and subcriteria. Its integration with the PQP, inspections, NCRs, and quality documentation can strengthen data-driven decision-making once the validation steps noted throughout this revision are completed.

This research is limited to one case study and a relatively small expert panel; generalization of the weights and rating intervals to other high-end residential projects requires testing on independent samples with different scale, organization, and location. Common-method bias and ceiling effects are also plausible given that most mean scores fall in a narrow 4.111-4.366 band and were collected from the same respondents who also supplied the correlated predictor scores; reporting score distributions, standard deviations, and subgroup comparisons in a future revision would help rule these effects in or out. Follow-up research can compare AHP with Fuzzy AHP, ANP, Best-Worst Method, or data-driven methods, and can add dimensions of cost, safety, sustainability, BIM, productivity, and post-construction performance.

CONCLUSION

This pilot study produced a preliminary QPI model consisting of five main criteria and 25 subcriteria to evaluate the quality performance of one high-end residential project at the construction stage; it demonstrates feasibility rather than establishing a generally applicable Jakarta residential-project index. After reconciling the AHP weights so that they sum exactly to 1 (Table 3), the corrected priorities are: Technical Quality 31.67%, User/Owner Perception and Satisfaction 27.07%, Material Quality 16.68%, Quality Management System 12.59%, and Implementation and Control Process 11.99%. In actual performance, Material Quality obtained the highest score (4.366) and Implementation and Control Process obtained the lowest (4.111). Integrating the normalized weights and actual performance results in a QPI of 4.212, placing the Widya Chandra Residence Project in the Rank-1, Excellent band of the corrected four-band scale. The regression decomposition indicates that the user dimension carries the largest coefficient in the composite average, while the defect and rework rate is the single indicator most in need of strengthening; because the regression outcome is derived from the same five predictors, this finding is descriptive rather than causal. The five criteria and 25 subcriteria (RQ1) were confirmed relevant by expert validation; AHP assigned Technical Quality and User Perception the two highest weights (RQ2); the case project's actual performance was rated above 4.0 on all five criteria, strongest in Material Quality and weakest in Implementation and Control Process (RQ3); and combining weight and performance produced an auditable QPI of 4.212 in the Excellent band, with the important caveat that this value and its threshold are project-specific and not yet transferable (RQ4). The proposed QPI is a preliminary decision-support framework whose accuracy, stability, and transferability require testing across independent residential projects, together with content and construct validity testing, objective (non-perceptual) technical evidence, and sensitivity analysis of the AHP weights before it is used for cross-project benchmarking or contractual decisions. For practitioners, QPI is recommended for use as a preliminary internal tool for periodic quality evaluation and control during project implementation, used alongside objective quality records and mandatory technical acceptance thresholds, rather than as a stand-alone inter-project benchmarking instrument at this stage. Quality improvement needs to continue to pay balanced attention to all dimensions, especially defect/rework control, quality management system effectiveness, the implementation process, and user response.

Future research should calibrate the model on multiple independent projects, add external and longitudinal validation, involve more experts and a larger, stratified respondent sample, test AHP sensitivity and compare it against ANP given the high C-E correlation observed here, incorporate objective defect and rework indicators alongside perception scores, and expand the index to cost, time, safety, sustainability, productivity, and digital-technology dimensions. The main limitation of this study remains its reliance on a single case study with a relatively small expert panel and no external or longitudinal validation, so the application of these results to other contexts requires further testing.

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