



# CONFERENCE ON FRONTIERS OF SCIENCE AND ENGINEERING • QATAR •

## DIGITALIZING CONSTRUCTION COST ESTIMATION IN SMES THROUGH TRACEABLE RECORDS AND COMPLETENESS CHECKS

**Raimov Bekzod Bahrom Ugli**

*Engineer, Production and Technical Department (PTO)*

*Atlant Construction, Uzbekistan*

**Abstract.** Digital estimation can accelerate the transfer of quantities and prices while also propagating unsupported inputs. This methodological paper proposes a practical workflow for construction small and medium-sized enterprises (SMEs) that connects each estimate item to its source, revision, measurement basis, rate evidence and reviewer decision. Six mandatory checks control release, while a cost-weighted indicator prioritizes unresolved, priceable items. Items without a defensible quantity or rate remain in a separate blocking queue and cannot be represented as zero-cost work. A fully specified synthetic example demonstrates the calculations and the distinction between a verified subtotal and an incomplete project estimate. The research contribution is the integration of traceability, release logic and review prioritization into a reproducible specification suitable for a spreadsheet-based prototype. The paper presents no firm survey or measured productivity improvement. A prospective validation protocol is provided to test defect detection, reproducibility and implementation burden before practical effectiveness is claimed.

**Keywords:** construction SMEs; cost estimation; digitalization; data provenance; quality gates; cost-weighted review

### 1 Introduction

An estimate is useful only when its quantities, prices and scope can be explained. A spreadsheet may produce an arithmetically correct total even when a drawing has been superseded, a unit conversion is wrong, or a missing material rate has been entered as zero. Digitalization therefore requires control over the evidence behind numbers, in addition to faster calculation. This problem is particularly relevant to a small estimating team that exchanges drawings, measurement sheets and supplier quotations through several separate files.

# CONFERENCE ON FRONTIERS OF SCIENCE AND ENGINEERING QATAR

The OECD identifies substantial differences in digital adoption among SMEs and describes barriers associated with capabilities, resources and increasingly complex technologies [1]. In construction, Dainty et al. caution that policies centred on building information modelling (BIM) do not automatically address the circumstances of small firms [2]. These sources support a proportionate implementation approach; they do not demonstrate the effectiveness of the workflow proposed here. A useful research question is how a firm can strengthen information control using its existing estimating tools before considering a wider software transition.

ISO 19650-1 describes principles for exchanging, recording, organizing and versioning information, while ISO 19650-4 addresses decision criteria during information exchange [3, 4]. RICS NRM 2 supplies a structured reference for detailed measurement [5]. These publications motivate clear sources, revisions and measurement rules. They are not treated as a substitute for the applicable national estimating basis or project contract. Similarly, the proposed workflow is informed by these principles without claiming certified ISO compliance.

## 2 Research question and contribution

The research question is how an SME can keep unsupported estimate inputs visible, trigger rechecking after revisions and prioritize financially significant unresolved items. The objectives are to define the evidence record, specify release conditions and establish an evaluation protocol.

The proposed contribution integrates provenance, completeness control and review prioritization into a testable workflow, including explicit handling of missing prices. Record keeping and quality checks are established practices; the contribution is their operational integration for estimate items. The output is a methodological specification and constructed demonstration.

## 3 Evidence records and release checks

The unit of analysis is one estimate item within a defined work package. Before calculation, the estimator creates a scope inventory from the applicable drawings, specifications and work breakdown. Each inventory entry receives a stable identifier and is linked to an estimate item, an explicitly documented exclusion, or an unresolved scope question. This inventory is essential: complete metadata for existing rows cannot reveal work that was never entered.

# CONFERENCE ON FRONTIERS OF SCIENCE AND ENGINEERING QATAR

Each item stores its work description, location, source document and page or drawing reference, document revision, measurement rule, quantity expression, unit, rate basis, price date, currency, tax treatment and responsible reviewer. A rate record also identifies whether labour, materials and equipment are included. A normative position must retain the actual database name, version and code supplied for the project. No position or rate is inferred merely because a description appears similar.

The record also logs the transformation from evidence to output: extraction, conversion, calculation, amendment and approval. This use of entities, activities and responsible people is consistent with the provenance concepts introduced by W3C PROV [6]. A practical prototype can implement these links in separate spreadsheet tables using stable identifiers; it need not implement the complete PROV vocabulary. Original files remain unchanged, and every amended calculation receives a dated version.

**Table 1 Mandatory item checks in the proposed workflow**

| Check    | Condition for passing                                   | Reason to block                                |
|----------|---------------------------------------------------------|------------------------------------------------|
| Source   | Evidence exists and resolves to the stated location     | Missing, inaccessible or unrelated evidence    |
| Revision | Evidence matches the agreed current project revision    | Superseded or ambiguous revision               |
| Unit     | Quantity and rate units agree; conversion is documented | Mismatch or unexplained conversion             |
| Quantity | Expression and scope can be independently reproduced    | Unverified measure, omission or duplication    |
| Rate     | Applicable basis, date and inclusions are documented    | Missing rate, source or applicability evidence |
| Review   | Named reviewer records a reasoned acceptance            | Open query or incomplete review                |

For item  $i$ , let  $g(i,k)$  equal 1 if check  $k$  passes and 0 otherwise. Unknown and not-yet-reviewed checks are coded 0, with a reason retained. The item release flag is defined

# CONFERENCE ON FRONTIERS OF SCIENCE AND ENGINEERING • QATAR •

below. A conditional allowance, if permitted by the estimate purpose, must have its own approved basis and visible classification; it cannot silently bypass the checks.

$$R_i = \prod_{k=1}^6 g(i, k)$$

An item is releasable only when  $R_i = 1$ . A final package requires all in-scope items to pass, all scope queries to be resolved and a documented reconciliation of exclusions. An incomplete internal draft may show verified subtotals, accompanied by its unresolved register, but cannot be labelled a complete project estimate. Passing the gates demonstrates that specified checks were completed; it does not guarantee that every source is factually correct.

Any change to supporting evidence invalidates the Review check for every affected item, together with its affected technical checks. A revised drawing reopens Revision, Quantity and Review, plus Unit or Rate where the changed work affects them. A changed quotation reopens Rate and Review, together with any affected unit or inclusion checks. The reviewer must approve the new version after technical revalidation; a historical approval cannot authorize changed values. Dependencies identify the affected items, and previous versions remain available. Duplicate identifiers, broken links and manual overrides are logged as exceptions requiring resolution.

## 4 Review prioritization and completeness reporting

The workflow separates release eligibility from review order. All blocking issues must ultimately be resolved, but a small team needs an intelligible sequence for doing so. Let  $P$  contain rows with a numerical candidate quantity and rate in compatible units. Their indicative extended values are  $v_i = q_i \times p_i$ . These values support triage only until their evidence is accepted; they are not approved costs. Rows with an unknown quantity, rate or unit conversion form the unpriceable set  $M$ .

$$C_N = \frac{\sum_{i=1}^N R_i}{N}, \quad N > 0$$

$$U_P = \frac{\sum_{i \in P} v_i (1 - R_i)}{\sum_{i \in P} v_i}$$

$C_N$  is the proportion of in-scope rows that pass every check, defined for  $N > 0$ . An empty inventory is reported as an unresolved scope condition, not as full completion.  $U_P$  is the unresolved share of the priceable candidate value; it is defined only when the denominator is positive. This demonstration assumes non-negative work-item values.

# CONFERENCE ON FRONTIERS OF SCIENCE AND ENGINEERING QATAR

Credits and deductions should be reported separately, because netting them against positive work could conceal unresolved exposure. Neither indicator is an estimate-accuracy score or a probability of financial loss.

The report always displays the size and identities of  $M$  beside  $U_p$ . Unpriceable items cannot receive a zero weight: their financial significance is unknown. They enter a mandatory clarification queue before numerical ranking. Within the remaining unresolved priceable rows, the proposed default order is decreasing  $v_i$ , with ties resolved by item identifier. Contractual deadlines and technical dependencies may justify a recorded change in this order. Ranking affects scheduling only and never permits low-value failures to pass.

The dashboard reports released-item count, verified subtotal, unresolved priceable value, the unpriceable register and unresolved scope entries. These measures describe different problems. A high row-completion percentage can coexist with substantial unresolved value, while unknown-rate items prevent interpretation as overall financial completeness.

## 5 Results of the constructed demonstration

Table 2 is a synthetic five-item example constructed solely to demonstrate the specification. All quantities, rates and defects are illustrative; CU denotes arbitrary currency units. These figures are not supplier prices, normative rates, project observations or findings from Atlant Construction. The scope inventory is assumed to contain exactly these five items so that the arithmetic can be reproduced without external data.

**Table 2 Synthetic estimate register before resolution**

| Item                | Quantity<br>rate                        | ×    | Candidate<br>value, CU | Status                         |
|---------------------|-----------------------------------------|------|------------------------|--------------------------------|
| A: floor<br>finish  | 100 m <sup>2</sup><br>CU/m <sup>2</sup> | × 4  | 400                    | All six checks pass            |
| B: concrete         | 10 m <sup>3</sup><br>CU/m <sup>3</sup>  | × 60 | 600                    | Superseded drawing<br>revision |
| C:<br>reinforcement | 20 kg<br>CU/kg                          | × 25 | 500                    | Rate evidence missing          |

# CONFERENCE ON FRONTIERS OF SCIENCE AND ENGINEERING QATAR

| Item                | Quantity<br>rate                           | × | Candidate<br>value, CU | Status                                 |
|---------------------|--------------------------------------------|---|------------------------|----------------------------------------|
| D:<br>waterproofing | 8 m <sup>2</sup><br>unknown rate           | × | Not<br>calculable      | Unpriceable;<br>clarification required |
| E: plaster          | 40 m <sup>2</sup> × 5<br>CU/m <sup>2</sup> |   | 200                    | All six checks pass                    |

Items A and E pass, giving  $C_N = 2/5 = 40\%$ . The priceable set contains A, B, C and E, with candidate value  $400 + 600 + 500 + 200 = 1,700$  CU. Its unresolved value is  $600 + 500 = 1,100$  CU, so  $U_p = 1,100/1,700 = 64.7\%$ . The verified subtotal is  $400 + 200 = 600$  CU. Item D remains unpriceable and is separately visible. Neither 600 CU nor 1,700 CU is a complete project total.

The resulting review sequence begins with clarification of D, followed by B and C among the priceable failures. B requires the current drawing and a repeated quantity check; C requires evidence that the candidate rate is applicable. A corrected numerical value alone cannot close either issue. The responsible reviewer must accept the supporting record, after which the gates and indicators are recalculated.

The demonstrated result is logical and arithmetic: the rules distinguish released work, quantified unresolved work and work whose value is unknown. The example does not establish error reduction, time savings or profitability. Incorrect scope definition can still omit important work.

For SME implementation, the initial artifact can be a controlled workbook containing source, item, rate, query and release tables. A later connection to CAD extraction or an estimating application should preserve the same identifiers and checks. Automated extraction may propose a value, but cannot create missing evidence. The practical trade-off is additional documentation effort in exchange for an inspectable decision process; the balance must be measured in use.

## 6 Validation protocol and limitations

Prospective evaluation should begin with authorized, anonymized estimate packages and an independently checked reference register. A controlled copy can contain documented test defects: absent prices, stale revisions, unit mismatches, duplicate scope and broken source links. The evaluator retains the defect key. Assessors

# CONFERENCE ON FRONTIERS OF SCIENCE AND ENGINEERING • QATAR •

then use the workflow without seeing that key, recording detected defects, missed defects, false alarms, time to resolve queries and time spent maintaining evidence records.

A second test asks an independent reviewer to reconstruct selected quantities and rate decisions using only the saved evidence. Selection should include high-value and randomly selected remaining rows, while explicitly testing every unpriceable condition in the controlled dataset. Results must report both successful and failed reconstruction, rather than only examples that worked. Revision tests should establish whether a changed source reopens all affected items and leaves unrelated items stable.

Before live evaluation, fix the rule definitions, exclusions, permitted overrides and reporting template. Determine sample size through feasibility assessment and a justified precision target. A pilot can assess usability; generalization requires several firms and project types. Limitations include unreliable sources, incorrect approvals, incomplete scope and the effort needed to maintain links. The workflow cannot independently establish market-price validity or certify compliance with local estimating requirements.

## 7 Brief conclusion

This paper proposes a traceable estimating workflow that combines six release checks, revision-aware revalidation and cost-weighted review. Its central safeguard is the explicit separation of verified subtotals, unresolved candidate values and unpriceable work. The constructed example establishes reproducible behaviour under stated assumptions, without presenting simulated figures as field evidence. The next research stage is an authorized pilot measuring defect detection, source reconstruction and documentation burden. Practical effectiveness remains a question for that evaluation, rather than a conclusion assumed from digitalization alone.

## References

- [1] OECD. (2021). The Digital Transformation of SMEs. OECD Studies on SMEs and Entrepreneurship. OECD Publishing. <https://doi.org/10.1787/bdb9256a-en>
- [2] Dainty, A., Leiringer, R., Fernie, S., & Harty, C. (2017). BIM and the small construction firm: A critical perspective. *Building Research & Information*, 45(6), 696–709. <https://doi.org/10.1080/09613218.2017.1293940>

# CONFERENCE ON FRONTIERS OF SCIENCE AND ENGINEERING • QATAR •

[3] International Organization for Standardization. (2018). ISO 19650-1:2018: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)—Information management using building information modelling—Part 1: Concepts and principles. ISO catalogue

[4] International Organization for Standardization. (2022). ISO 19650-4:2022: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)—Information management using building information modelling—Part 4: Information exchange. ISO catalogue

[5] Royal Institution of Chartered Surveyors. (2021). NRM 2: Detailed measurement for building works (2nd ed.; reissued as practice information in October 2022 without material changes). RICS. RICS publication

[6] Gil, Y., & Miles, S. (Eds.). (2013). PROV Model Primer. W3C Working Group Note, 30 April 2013. W3C publication