HVAC.BIS: AN AI-ASSISTED HVAC BID INTELLIGENCE AND COMMERCIAL VALIDATION SYSTEM

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ABSTRACT

Heating, Ventilation and Air Conditioning (HVAC) bid preparation requires contractors and estimators to interpret technical specifications, drawings, equipment schedules and Bills of Quantities (BOQs), and then translate the available information into preliminary engineering estimates and commercial proposals. Since project information is often distributed across multiple documents, manual review can make it difficult to identify missing details, uncertain values and conflicting requirements. This paper presents HVAC.BIS (HVAC Bid Intelligence System), an AI-assisted workflow intended to support HVAC tender analysis and bid preparation. The system provides two input paths: document-driven analysis, in which tender documents are uploaded, and requirement-driven analysis, in which project details are entered directly. Relevant information is extracted and organized into structured project data. A cross-verification stage highlights missing, uncertain and conflicting values for human review. The workflow further supports preliminary HVAC calculations, equipment recommendations, BOQ generation and commercial calculations, followed by contractor validation. The design separates AI-assisted interpretation from explicit calculation and validation logic so that generated information is not treated as an automatically approved engineering decision. The paper describes the problem context, related work, proposed workflow, system architecture, methodology, implementation scope, and an evaluation framework. The current system is positioned as a decision-support tool; final engineering design, equipment selection and bid approval remain the responsibility of qualified professionals. Quantitative claims about accuracy, time savings or commercial outcomes are not made without documented experimental evidence.

KEYWORDS

HVAC, Artificial Intelligence, Tender Analysis, Bid Intelligence, Document Processing, Cross-Verification, HVAC Estimation, Bill of Quantities, Commercial Validation.

1. INTRODUCTION

Heating, Ventilation and Air Conditioning systems contribute to thermal comfort, indoor air quality and ventilation in buildings such as offices, hospitals, hotels, shopping centres and industrial facilities. The preparation of an HVAC bid is a multi-stage activity that combines technical interpretation with commercial estimation. A contractor may need to review tender conditions, mechanical specifications, equipment schedules, drawings, BOQs, addenda and project requirements before preparing a proposal.

The information needed for a bid is rarely contained in a single location. Equipment capacity may appear in a schedule, quantity may be listed in a BOQ, and installation requirements may be described in a specification. These sources may be incomplete or inconsistent. An estimator must locate the relevant statements, compare them, determine which issues require clarification and then prepare quantities and costs. This work can be repetitive and may expose the bid to omissions or commercial risk.

HVAC.BIS is designed to organize these tasks through a common workflow. It accepts uploaded tender documents or directly entered project requirements, extracts relevant information, highlights issues for review and supports preliminary calculations and commercial preparation. The system is intended to assist the estimator by improving visibility and organization; it does not replace professional engineering judgement.

1.1 Background and Motivation

Construction projects depend on coordinated information from owners, consultants, contractors, suppliers and specialist subcontractors. In HVAC projects, the estimator must interpret requirements that relate to cooling capacity, airflow, ventilation, equipment type, electrical characteristics, controls, piping, ductwork, insulation, drainage and installation. The required level of detail varies with project size and tender maturity. A preliminary bid may be prepared from incomplete information, but assumptions and exclusions must be made visible.

Document digitization and language technologies provide opportunities to support the early stages of tender review. PDF text extraction can make selectable text available for processing, while optical character recognition can convert text in scanned pages into machine-readable form. AI models can assist in interpreting natural-language requirements and organizing extracted facts. However, extraction quality depends on document quality, layout, terminology and the model configuration. Tables and engineering drawings may require additional checking, and OCR output should not be assumed to be error-free.

1.2 Problem Statement

HVAC contractors face difficulty in manually reviewing complex tender documents, locating HVAC requirements, identifying missing or conflicting information, estimating equipment and material quantities, and preparing commercial bids. These fragmented activities consume time and may introduce estimation and coordination risks. A unified HVAC-focused workflow is needed to organize project information, highlight items requiring clarification and support a consistent bid-preparation process.

1.3 Research Aim and Objectives

The aim of HVAC.BIS is to develop an AI-assisted system that supports the preparation and review of HVAC bids by connecting document interpretation, requirement structuring, preliminary engineering support and commercial estimation.

- Provide document-driven and requirement-driven input paths for HVAC projects.
- Extract relevant information from available tender documents and organize it into structured project data.
- Identify missing, uncertain and conflicting information and direct it to contractor review.
- Support preliminary HVAC calculations and equipment recommendations based on available project inputs.
- Generate itemized BOQ information and configured commercial calculations.
- Maintain human review as a required stage before final bid approval.

1.4 Scope of the Work

The project focuses on the bid-preparation workflow rather than detailed design certification or automatic construction approval. Its intended users include HVAC contractors, estimators, mechanical engineering firms and tender-preparation teams. The current scope includes document and requirement inputs, information extraction, cross-checking, preliminary calculation support, equipment recommendations, BOQ generation and commercial calculations. Outputs remain subject to source verification and professional review.

1.5 Organization of the Paper

The remainder of this paper reviews related work and existing approaches, describes the proposed system and architecture, explains the methodology and implementation scope, and presents an evaluation plan, discussion, limitations and future enhancements.

2. RELATED WORK

The proposed system draws on research and established practices in construction information management, document processing and HVAC engineering. Building information modelling (BIM) research has emphasized the value of structured information exchange across the building lifecycle. Eastman et al. describe BIM as a digital representation and information-management approach that can support coordination among project participants [1]. Although HVAC.BIS is not a BIM authoring or native CAD interpretation platform, the need to organize information from multiple project sources is closely related to the broader challenge of construction information coordination.

Construction cost estimation and quantity takeoff depend on interpreting drawings, specifications and project scope. Manual takeoff workflows require estimators to identify components, measure or count quantities, record assumptions and connect those quantities to rates. Automated takeoff research and commercial tools seek to reduce repetitive measurement and data-entry work. However, extracted quantities still need review because drawing quality, scale, symbols, revisions and project-specific conventions affect interpretation. HVAC.BIS focuses on connecting extracted tender information with validation and bid-preparation stages rather than claiming fully automated interpretation of all CAD formats.

Document analysis systems commonly combine text extraction, OCR, classification and information extraction. Text-based PDF processing can retrieve selectable content, while OCR is used when pages contain scanned images. The resulting text may then be classified and converted into structured fields. For technical documents, the extracted value should be associated with its source and checked against related documents. A source reference improves traceability, but it does not guarantee that the original source is correct.

Artificial intelligence and large language models can help interpret unstructured text and map varied wording to a structured representation. Their outputs are probabilistic and can be affected by ambiguous instructions, poor source quality or missing context. For this reason, AI-generated extraction should be validated before it is used in calculations or commercial outputs. A practical architecture separates language interpretation from deterministic operations such as arithmetic, rule checks and configured pricing calculations.

2.1 Existing Approaches and Their Limitations

Approach	Typical strength	Potential limitation	HVAC.BIS design response
Manual tender review	Experienced estimator judgement and contextual understanding	Time-consuming document search and repeated data entry	Organize extracted requirements and flag review items
Construction takeoff tools	Support counting and measurement from drawings	May not cover the full HVAC bid and commercial workflow	Connect project information to HVAC-focused bid stages
Document and contract intelligence	Identify clauses, obligations and document risks	May not produce HVAC sizing, BOQ and pricing outputs	Combine document checks with preliminary HVAC and commercial workflow
General-purpose AI assistants	Natural-language interaction and summarization	May not preserve structured evidence or project-specific validation	Use structured outputs, verification statuses and human review

2.2 Research Gap and Design Position

The design opportunity addressed by HVAC.BIS is the integration of HVAC-oriented document review with requirement processing, cross-verification, preliminary calculation support and commercial preparation. The system does not claim that existing products lack all these capabilities; rather, it provides a focused workflow for bringing related bid activities into one project process. Its distinguishing design principle is that AI assists with understanding information, while calculation logic and contractor review govern the use of that information.

3. EXISTING SYSTEM

In a conventional bid-preparation workflow, an estimator receives tender documents, manually searches for relevant requirements, records equipment and material details, checks the BOQ against specifications and drawings, obtains or applies rates, and prepares a quotation. Supporting spreadsheets and document viewers may be used at different stages. This workflow benefits from the estimator's experience but can involve repeated switching between documents and tools.

A key challenge occurs when the same requirement is represented differently across sources. For example, an equipment schedule may show one quantity while the BOQ lists another. A missing capacity or room detail may require a clarification request. If the issue is not identified early, the estimate may be based on an unverified assumption. HVAC.BIS is intended to make such issues more visible before the contractor finalizes the bid.

4. PROPOSED SYSTEM

HVAC.BIS extends the conventional tender workflow with two input paths and a shared processing sequence. The first path is Document Analysis, where the contractor uploads tender specifications, BOQs and other supporting files. The second path is Requirement Analysis, where project details are entered directly. Both paths produce structured project information that can be checked and used by downstream workflow stages.

4.1 Document Analysis Path

The contractor uploads a tender document or supporting file. The document-processing stage extracts available content from the file. Selectable text can be processed through PDF text extraction, while scanned content may require OCR where that capability is configured. Extracted information is interpreted and organized into relevant HVAC fields. The system should retain source identifiers and page references wherever available so that a reviewer can return to the original evidence.

4.2 Requirement Analysis Path

The contractor enters project information such as building use, project location, area, occupancy, zones and known equipment requirements. The system organizes the submitted details into the project structure used by the document path. The requirement path is useful when the contractor wants to begin a preliminary analysis or when a complete tender package is not available. Missing inputs should be explicitly identified because incomplete requirements limit the reliability of subsequent calculations.

4.3 Unified Project Information

A common project representation is important because it prevents the document path and requirement path from producing unrelated downstream formats. The structured information may include project metadata, source documents, equipment records, quantities, capacities, airflow values, technical specifications and review statuses, depending on what is actually available in the input. Each value should be distinguished as extracted, user-entered, calculated or awaiting confirmation.

4.4 Cross-Document Verification

The verification stage compares related information from the available sources. It can identify missing values, uncertain extraction results and discrepancies between documents. For example, if a drawing note and a BOQ contain different equipment quantities, both values should be retained and the issue marked for review. The system should not silently select one value unless a documented precedence rule or an authorized user decision supports that selection.

Status	Meaning	Expected handling
PRESENT	A required value is available in the reviewed input	Display the value and its source where available
MISSING	A required value was not found	Request clarification or mark as an assumption only when authorized
UNCERTAIN	The extracted value or interpretation is unclear	Ask the estimator to inspect the source
CONFLICT	Two or more sources provide inconsistent values	Show the competing values and request resolution
NEEDS_REVIEW	The item requires human validation	Prevent unreviewed critical information from being treated as approved

4.5 Preliminary HVAC and Commercial Workflow

After information review, the workflow supports preliminary HVAC calculations and equipment recommendations. It then generates BOQ items and applies configured commercial calculations such as item costs, markup and GST. These outputs depend on input completeness, engineering assumptions, quantity methods and the rates supplied by the contractor. The contractor or qualified engineer must validate the results before using them as a final tender submission.

5. SYSTEM ARCHITECTURE

HVAC.BIS is organized as a web-based application with a user interface, workflow orchestration, document and AI processing, structured project storage, calculation and commercial stages, and a contractor review step. The architecture is intended to keep information processing distinct from the final approval decision. The specific deployment and service configuration should be documented according to the version used in the project.

5.1 Presentation Layer

The presentation layer provides the contractor-facing interface for entering project requirements, uploading documents, viewing extracted information, reviewing validation statuses and inspecting generated bid outputs. The frontend technologies used in the project include Next.js, React and TypeScript. The interface should make the source and status of important values understandable so that users can identify which items are confirmed and which require attention.

5.2 Workflow Orchestration Layer

SNS Agent Workbench is used to organize the project workflow. At a functional level, the workflow connects input reception, document or requirement processing, information extraction, structured project data, cross-verification, preliminary HVAC processing, BOQ and commercial stages, and final review. These descriptions represent workflow responsibilities; exact node names and internal configurations should be reported only when confirmed from the actual workbench.

5.3 AI and Document Processing Layer

The AI integration assists with interpreting natural-language requirements and extracting relevant HVAC information from available document content. PDF processing handles document input, while OCR may be used for scanned pages when enabled in the implementation. The specific model provider and OCR service must be stated using the actual configuration used in the deployed project. AI output is treated as candidate information and should be checked against the source.

5.4 Data and Storage Layer

Supabase is used for backend storage. Uploaded tender files are stored in Supabase Storage, while project-related metadata and structured information can be maintained in the associated database. A project may be associated with document identifiers, file paths, document types, processing status and page counts. The data model should preserve relationships between projects, uploaded documents, extracted information and generated outputs. The exact schema should be included in a later implementation appendix if required by the publication venue.

5.5 Calculation and Commercial Layer

The calculation and commercial stages process validated or explicitly reviewed inputs. Preliminary engineering calculations should use documented formulas and assumptions. BOQ generation should connect quantities to their source or calculation method wherever possible. Pricing should use contractor-provided or otherwise verified rates; benchmark values must not be described as live supplier prices. Markup and tax calculations should be configurable according to the applicable commercial context.

5.6 Human Review and Control

Human review is a core architectural control. The contractor or engineer inspects missing and conflicting information, checks assumptions, validates equipment recommendations and approves the final proposal. The system should communicate uncertainty clearly and should not present an AI-generated value as an engineering-certified result.

Layer	Responsibility	Project technology / component
Presentation	User interface and project dashboard	Next.js, React, TypeScript
Workflow	Connect processing stages	SNS Agent Workbench
Document and AI	Extract and interpret input information	PDF processing, AI/LLM integration
Storage	Store uploaded files and project data	Supabase Storage and database
Validation and calculations	Check data and support preliminary estimates	Workflow validation and calculation logic
Review	Contractor confirmation and proposal review	Human-in-the-loop workflow

6. METHODOLOGY

The methodology follows a sequence of repeatable stages that transforms tender documents or contractor requirements into a reviewable bid package. The stages are designed to make the origin and status of information visible and to separate extraction from validation and calculation.

6.1 Requirements Analysis

The first stage identifies the intended users, input types and expected outputs. The primary users are HVAC contractors, estimators and mechanical engineering teams. Their tasks include submitting tender documents, entering project requirements, reviewing extracted information, resolving discrepancies, inspecting preliminary calculations, checking BOQ items and validating commercial outputs. These tasks define the functional requirements of the system.

6.2 Document Intake and Extraction

Uploaded files are received and stored for processing. The document pipeline extracts available text and other supported content. For scanned pages, OCR is required to convert image-based text into machine-readable content. The quality of the output depends on scan resolution, page orientation, table layout, symbols and document condition. Extracted text should therefore be treated as an intermediate result rather than a guaranteed representation of the source.

6.3 HVAC Information Structuring

The extraction stage identifies relevant HVAC facts when they are present in the input. Examples include equipment type, quantity, nominal capacity, airflow, manufacturer or model references, electrical details and technical requirements. The extracted facts are mapped into structured project fields. A value should retain its unit and source context where available. Values that are not present should remain missing rather than being filled with unsupported assumptions.

6.4 Cross-Verification and Conflict Handling

The system compares related values across the available inputs. A conflict can occur when two documents specify different quantities, capacities or equipment details. The verification process records the competing values and identifies the issue for contractor review. If a document hierarchy or contract precedence rule is used, it should be explicitly represented and applied only where the project configuration supports it.

6.5 Preliminary HVAC Calculation

Preliminary calculation uses available project inputs to support early estimation. Cooling capacity may be expressed in tons of refrigeration (TR) or BTU per hour, while airflow may be represented in cubic feet per minute (CFM). The conversion 1 TR = 12,000 BTU/h is a standard unit relationship, but a reliable cooling-load estimate requires more than floor area. Occupancy, envelope properties, solar gains, lighting, equipment loads, ventilation, climate and room-level conditions may all affect the result. Therefore, outputs from incomplete inputs must be identified as preliminary.

6.6 Equipment Recommendation

Equipment recommendations are based on the project requirements and preliminary capacity information available to the workflow. Possible equipment categories include air handling units (AHUs), fan coil units (FCUs), split systems, variable refrigerant flow (VRF) systems and chillers, depending on the application. A recommendation should be checked against verified manufacturer data, tender constraints, electrical requirements, service conditions and engineering design requirements. The system should not invent model numbers or claim catalogue verification without a trusted data source.

6.7 BOQ and Commercial Preparation

The BOQ stage organizes equipment and material items with their estimated quantities and units. Items may include indoor and outdoor units, ducts, piping, insulation, drainage, cabling, supports and installation activities where relevant to the project scope. The commercial stage applies available unit rates, markup and tax settings to calculate totals. Quantity and pricing assumptions should be visible to the estimator.

6.8 Contractor Review

The final methodology stage presents the extracted facts, validation issues, preliminary calculations, equipment recommendations, BOQ and commercial summary for review. The contractor confirms or corrects the information and determines whether the proposal is ready for submission. The final decision remains with the contractor and qualified engineering personnel.

7. IMPLEMENTATION DETAILS

The current project implementation combines a web interface, a workflow environment, backend storage and AI-assisted processing. The frontend uses Next.js, React and TypeScript to present the project workflow. SNS Agent Workbench connects the processing stages. Supabase is used to store uploaded documents and project-related data. PDF processing and AI/LLM integration support the extraction and interpretation of tender information.

7.1 Input and Project Creation

A project begins when the contractor supplies a tender document or enters requirements. The system associates the input with a project context so that subsequent extraction and validation results can be organized under the same project. Uploaded files are stored in the configured Supabase Storage bucket, and associated project metadata is maintained in the backend data store.

7.2 Extraction Output and Structured Records

The AI-assisted extraction stage converts relevant input content into structured facts for downstream use. A conceptual record may contain an equipment category, quantity, capacity, unit and source reference. The exact field names and schema depend on the implementation. The paper should not imply that every possible drawing symbol, scanned table or CAD entity is automatically interpreted unless that capability has been implemented and tested.

7.3 Verification Output

Verification results communicate whether a value is present, missing, uncertain or conflicting. For a conflict, the system should show the source values and make the need for review explicit. A reviewer should be able to return to the relevant source document where page-level references are available. This approach helps prevent an extracted value from being mistaken for a confirmed project requirement.

7.4 Preliminary Calculation and BOQ Output

The calculation stage uses the available structured information to support preliminary estimation. The BOQ stage organizes quantities into an itemized list that can be checked by the estimator. The commercial stage calculates totals from configured rates and rules. Since the reliability of the result depends on the input and assumptions, the system should expose the relevant values and allow review before final proposal generation.

7.5 Security and Data Handling Considerations

Tender documents and commercial information may be confidential. Access to project files should be limited to authorized users, and API credentials must not be embedded in publicly accessible source code. Environment secrets should be stored using appropriate configuration controls. The system should avoid exposing one contractor's project information to another contractor. Where authentication, role-based access or complete multi-tenant isolation is not fully implemented, those capabilities must be described as work in progress rather than completed features.

7.6 Current Scope and Unimplemented Capabilities

Capability	Status to report in this paper
Document and requirement input paths	Included in current project scope
PDF information extraction	Implemented
Preliminary HVAC calculations	Implemented; engineering validation required
Equipment recommendations	Implemented; requires engineering validation
BOQ and commercial calculations	Implemented
Cross-checking and review statuses	Implemented
Proposal generation	Implemented
Live semantic RAG / vector database	Not implemented; future enhancement
Native DWG/DXF parsing	Not implemented; future enhancement
Live manufacturer or supplier pricing	Not implemented; future enhancement
Complete multi-tenant deployment and enterprise RBAC	Not fully implemented

This distinction is important for research integrity. The paper describes the current implementation and identifies advanced capabilities as future work. It does not claim a live vector retrieval system, native CAD parser or supplier-price integration where these are not present.

8. RESULT ANALYSIS AND EVALUATION PLAN

The system should be evaluated across functional correctness, extraction quality, verification behaviour, calculation consistency, BOQ quality, commercial arithmetic and usability. A successful workflow demonstration alone does not establish engineering accuracy or measurable time savings. Each reported result should identify the test data, sample size, test conditions and evaluation method.

8.1 Functional Testing

Functional testing checks whether the main workflow stages execute as expected. Test cases should cover project creation, document upload, requirement entry, extraction output, status generation, preliminary calculation, BOQ generation, commercial calculation and proposal review. Negative cases should include invalid files, incomplete requirements, unreadable pages and missing commercial rates.

Test area	Example test	Expected outcome
Document intake	Upload a supported tender PDF	File is stored and associated with the correct project
Requirement input	Submit a project with required and optional fields	Entered values are represented in the project data
Extraction	Use a test document with known HVAC facts	Relevant facts are extracted for reviewer inspection
Missing data	Omit a required project value	The system flags the value as missing or requiring review
Conflict detection	Provide different quantities in two sources	Both values are retained and a conflict is raised
Calculation	Use a documented input set and formula	Output matches the independently calculated expected value
BOQ and pricing	Use known quantities and configured rates	Items and totals follow the configured calculation rules

8.2 Extraction Quality

Extraction quality can be evaluated using a set of tender pages with manually annotated HVAC facts. For each field, the evaluator compares the extracted value with the reference annotation. Exact-match accuracy may be used for categorical fields and normalized numeric comparison for quantities and capacities. The test should record unit normalization, missing-value handling and whether the source page was correctly identified. Results should be reported separately for selectable-text PDFs and scanned documents because their extraction conditions differ.

8.3 Conflict Detection Quality

Conflict detection can be assessed using test documents containing known matching, missing and conflicting values. Reviewers can compare the system's status with the expected status. Precision measures the proportion of flagged conflicts that are genuine conflicts, while recall measures the proportion of known conflicts that the system successfully identifies. If the test set is small or manually constructed, the results should be described as prototype validation rather than broad performance evidence.

8.4 Calculation and Commercial Validation

Preliminary calculations should be checked against independently computed reference examples using the same assumptions and units. Commercial totals should be verified using a hand-calculated test set covering item subtotals, markup, taxable value and GST. Engineering validation must be performed by a qualified HVAC professional for any result intended to represent a real project. Unit conversion correctness does not establish that the underlying cooling-load assumptions are appropriate.

8.5 Usability Evaluation

A usability study may ask HVAC estimators or domain experts to complete tasks such as uploading a tender, locating a conflict, reviewing a BOQ item and checking a commercial summary. Data may include task completion, time on task, observed errors and participant feedback. A survey should record the participant role and experience level without collecting unnecessary personal information. Any user study should follow the institution's applicable ethics and consent requirements.

8.6 Reporting of Results

No measured accuracy, time-saving percentage, cost reduction or bid-success improvement is claimed in this draft because no validated experimental dataset or measured results have been supplied. After testing, the authors should replace this evaluation plan with the actual test setup, sample size, results table, error analysis and limitations. Unsupported numerical claims should not be added for publication.

9. DISCUSSION

HVAC.BIS addresses a workflow problem rather than a single document-reading task. The value of the proposed system comes from connecting information extraction with verification, preliminary estimation and commercial preparation. An extracted equipment quantity becomes more useful when it is associated with a source, compared with other project information and made available to the estimator as part of a BOQ workflow. The same principle applies to missing values and conflicting requirements.

The separation between AI-assisted interpretation and deterministic calculation is an important design decision. Language models can help interpret varied expressions and organize information, but their output can be incomplete or incorrect. Calculation logic is more suitable for repeatable arithmetic and configured rules. Human review is necessary where documents disagree, assumptions affect the result or professional judgement is required. This division of responsibilities can make the system easier to inspect and test.

The system also has practical constraints. Poor-quality scans, complex tables, ambiguous abbreviations and engineering drawings can reduce extraction quality. A source reference helps the estimator inspect the original page, but the source itself may be outdated or inconsistent. Similarly, a preliminary equipment recommendation may not account for every manufacturer constraint or detailed design condition. These issues mean that HVAC.BIS should be treated as a decision-support workflow.

9.1 Practical Value to Target Users

- HVAC contractors can organize tender information and identify issues requiring clarification.
- Estimators can review extracted values and structured BOQ information rather than relying only on scattered manual notes.
- Mechanical engineering teams can use preliminary outputs as a starting point for professional review.
- Project managers can receive a more structured view of missing requirements and bid-preparation status.

9.2 Risks and Responsible Use

Incorrect extraction or an unresolved conflict can affect the quantity and price of a bid. The interface should make uncertain values visible and should avoid presenting preliminary outputs as certified engineering results. Tender documents may contain confidential project and pricing information, so storage access, credentials and data sharing must be controlled. Users should be able to identify the source of critical information and correct errors before the proposal is finalized.

10. LIMITATIONS AND FUTURE ENHANCEMENTS

The current system has limitations that should be considered when interpreting its outputs. Extraction depends on the quality and format of source documents. Complex scanned tables and drawing symbols may not be reliably interpreted by basic text extraction. Preliminary calculations depend on the completeness of the inputs and the assumptions used. Equipment recommendations require verification against current manufacturer information and project-specific engineering requirements. Commercial calculations depend on the rates and tax settings supplied by the user.

10.1 Future Enhancements

- Retrieval-based access to contractor-approved historical bids, after a validated retrieval pipeline is implemented.
- Semantic vector search for locating relevant company reference passages.
- Advanced drawing analysis and native DWG/DXF support with suitable engineering validation.
- Integration with verified manufacturer catalogues and supplier quotation sources.
- Expanded authentication, role-based access, multi-tenant isolation and audit trails.
- Quotation revision history and visual comparison of successive bid versions.
- Broader evaluation using real or appropriately anonymized tender documents and HVAC expert review.

These enhancements should be prioritized according to user needs, technical feasibility and measurable value. New AI capabilities should be introduced with test data, clear acceptance criteria and a human-review process.

11. CONCLUSION

HVAC.BIS presents an AI-assisted approach to organizing HVAC tender analysis and commercial bid preparation. The system accepts project information through document upload or direct requirement entry, extracts relevant information, structures project data and highlights missing, uncertain or conflicting values. It further supports preliminary HVAC calculations, equipment recommendations, BOQ generation and configured commercial calculations before the contractor reviews the proposal.

The proposed workflow is designed to reduce fragmented manual effort and make important issues more visible during bid preparation. Its architecture separates AI-assisted interpretation from explicit calculation and validation logic, while retaining the contractor and qualified engineer as the final decision-makers. This is particularly important because document extraction can be imperfect and preliminary calculations depend on assumptions and source completeness.

The current implementation should be evaluated through documented functional tests, extraction comparisons, conflict-detection cases, calculation checks and feedback from HVAC professionals. Future work can extend the system through historical reference retrieval, advanced drawing analysis, verified supplier data and stronger enterprise controls. HVAC.BIS is therefore positioned as a practical decision-support system for HVAC bid preparation, with further validation required before making claims about measurable performance or engineering outcomes.

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Note: The reference list above contains standards and books relevant to the HVAC and construction-information context. Add peer-reviewed papers directly related to AI-based document extraction, construction quantity takeoff and tender analysis after verifying the exact bibliographic details and the target publication's citation style.