Snehit Tayade, 2026, 14:5
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

Fire-Fighting Systems in Semiconductor Chiller Buildings Using A BIM Framework: A Review

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Abstract- Semiconductor manufacturing facilities depend on highly reliable utility infrastructure, including chiller buildings that support continuous process cooling. A fire in such a facility can threaten personnel, critical equipment, production continuity and the wider supply chain. Fire-protection design therefore requires careful coordination among sprinkler networks, standpipes, pumps, valves, pipe supports, building structure and other mechanical, electrical and plumbing (MEP) services. Conventional two-dimensional (2D) computer-aided design drawings remain useful for drafting but provide limited spatial insight and can make interdisciplinary coordination and revision control difficult. This review examines the application of Building Information Modeling (BIM) to the design and coordination of fire-fighting systems, with particular emphasis on conversion of 2D AutoCAD layouts into a fabrication-oriented three-dimensional (3D) model for a semiconductor chiller building. Literature on BIM-based fire safety, sprinkler design, MEP modelling, automation, clash detection and model-based documentation is synthesized to identify practical benefits and persistent limitations. A workflow using Autodesk Revit, Navisworks and Dynamo is discussed, including model setup, component placement, coordination, standards-based review and production of schedules and drawings. The review indicates that BIM can improve visualization, information consistency and early identification of spatial conflicts; however, geometric coordination alone does not establish hydraulic adequacy or full code compliance. Reliable implementation requires validated design inputs, suitable levels of development, disciplined information management and review by qualified fire-protection professionals. The paper proposes a structured workflow and highlights research needs in automated code checking, measurable productivity evaluation and BIM interoperability for high-hazard industrial facilities.

Keywords Building Information Modeling (BIM); fire-fighting system; semiconductor facility; chiller building; MEP coordination; clash detection; Autodesk Revit; NFPA.

I. INTRODUCTION

Semiconductor fabrication depends on tightly controlled environmental and process conditions. Chiller buildings typically contain large cooling equipment, pumps, electrical systems, distribution pipework and associated control infrastructure. A fire incident in these utility spaces can cause direct safety hazards and interrupt operations that depend on uninterrupted cooling. Fire-fighting systems must therefore be designed, coordinated and documented with a high degree of reliability.

A conventional 2D workflow communicates plans, sections and details through separate views. Although established and widely used, this approach can make it difficult to understand congested overhead services, verify clearances and maintain consistency when layouts change. Errors may only become evident during installation, when relocation of pipes, hangers or other services can lead to rework and schedule impacts. BIM provides a data-rich 3D environment in which geometry, system information and documentation can be coordinated within a shared model [2–4].This paper reviews BIM-based fire-protection design and its relevance to a semiconductor chiller building. The focus is not to claim completed design results, but to synthesize prior work and define a practical workflow for developing and reviewing a coordinated fire-fighting model from client-provided CAD drawings.

1. Review Scope And Approach

The review is organized around five connected themes: (i) BIM and fire-safety engineering; (ii) sprinkler and fire-fighting system modelling; (iii) MEP automation and parametric modelling; (iv) clash detection, collaboration

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and model information management; and (v) standards, limitations and future research. The starting literature set is drawn from the project synopsis, including studies on BIM-based fire safety, sprinkler-system design, MEP modelling, value engineering, drawing interpretation and coordination strategies [1–5, 7, 9–11].

The synthesis is qualitative. Reported outcomes from individual studies are treated as study-specific findings rather than universal performance guarantees. In particular, results from general buildings or algorithmic drawing-recognition experiments should not be assumed to transfer directly to semiconductor utility facilities without validation.

For this narrative review, the cited studies were compared qualitatively according to their relevance to fire-safety engineering, sprinkler design, MEP coordination, automation and industrial-facility application. Greater weight was given to publications that discuss fire-protection-specific limitations or multidisciplinary coordination. The review does not claim a systematic database search, exhaustive screening or statistical meta-analysis. Accordingly, findings are synthesized to identify practical implications and research gaps rather than to estimate a universal percentage improvement in cost, time or safety performance [2–4,7].

2. Bim In Fire-Safety Engineering

BIM is a collaborative modelling process that connects three-dimensional geometry with object properties, relationships and project documentation. In fire protection, a coordinated model can represent sprinkler heads, branch lines, mains, risers, valves, pumps, hydrants, standpipes and supports. It can also link components to system identifiers, sizes, elevations, material specifications and documentation requirements. This creates a common spatial reference for design, coordination and construction planning.

Davidson and Gales [2] describe BIM as an increasingly relevant platform for fire-safety engineering while identifying adoption barriers, including limited integration between design models and fire-engineering analysis. Their review indicates that BIM is valuable for information exchange and lifecycle coordination, but fire-safety analysis often relies on separate tools and data-transfer processes. Consequently, BIM should be understood as an information and coordination environment, not a replacement for engineering calculations or specialist fire modelling.

Ahmadi et al. [3] report that practitioners value BIM for visualization and identifying conflicts between services, while noting that BIM models do not necessarily verify all sprinkler-code requirements automatically. For example, correct component placement requires more than placing sprinkler symbols in a 3D room: obstruction rules, coverage areas, hazard classifications, spacing and other prescriptive requirements must also be assessed. This distinction is particularly important in industrial buildings where equipment density and access requirements can complicate layouts.

3. Fire-Fighting System Modelling And Automation

A BIM model for a chiller building should be built from verified design information. Relevant objects may include sprinkler heads, pipe segments, fittings, valves, risers, fire department connections, pumps and pipe hangers or supports. Component families should contain appropriate geometric representations and useful parameters. Model development should follow the project's required level of development (LOD) and the intended use of the model; LOD 350–400 may be appropriate where interfaces, supports and fabrication-oriented information are required, provided the project specification defines these requirements clearly.

Feng and Chen [4] examined the development of construction MEP BIM models for a fire-fighting system and discussed structured component information and visual-programming methods. Their work illustrates how rules and scripts can reduce repetitive modelling tasks and help classify components consistently. In a Revit-based workflow, Dynamo can assist with repeated placement, parameter assignment, support layout and schedule preparation. Automation should nevertheless be controlled by input checks and human review because scripts can reproduce incorrect assumptions at scale.

Research into automatic sprinkler-layout generation also suggests potential for reducing repetitive drafting effort. Zeng et al. [1] investigated an AI-supported approach for sprinkler placement and reported promising performance for coverage and design-time

reduction in their evaluated floorplans. However, the authors also identified limitations in generating connected pipe networks. This reinforces the need to treat point placement, pipe routing, hydraulic design and code verification as separate but coordinated tasks.

Recent work on MEP drawing interpretation and pipeline coordination further indicates that graph-based drawing understanding and optimization algorithms may assist component recognition and layout planning [8, 9]. These methods may become useful for converting legacy CAD information into BIM objects, but their outputs require validation against the original drawings, project specifications and design intent.

4. Bim Coordination And Clash Detection

The principal coordination advantage of a 3D BIM environment is the ability to inspect the fire-fighting system alongside architectural, structural, HVAC, electrical and process services. Potential conflicts include pipes intersecting beams or ducts, sprinkler heads obstructed by equipment, inadequate access to valves, support clashes, insufficient maintenance clearances and inconsistent elevations. Detecting such issues before installation can support more informed design decisions and reduce avoidable site modifications.

A practical coordination process typically combines model federation with rule-based or geometric clash tests. Discipline models are linked or aggregated in a coordination tool such as Navisworks, after which clashes are grouped, assigned to responsible disciplines, reviewed and resolved. Not every geometric intersection represents a genuine construction problem: insulation, tolerances, maintenance access, installation sequence and approved routing may affect the severity of a clash. Teams should therefore classify issues, document decisions and re-run tests after revisions.

BIM-based collaboration also depends on consistent model ownership, naming conventions, coordinates, levels, worksets, version control and communication protocols. Teo et al. [7] emphasize the role of both technology and management practices in MEP coordination. Software alone does not ensure coordination; reliable outcomes require agreed procedures and timely participation by relevant disciplines.

II. PROPOSED WORKFLOW FOR A SEMICONDUCTOR CHILLER BUILDING

1. Drawing Review And Model Setup

The workflow begins by reviewing the approved 2D AutoCAD drawings, specifications, equipment layouts and relevant fire-protection design documents. Units, coordinate systems, levels, drawing revisions and key dimensions should be confirmed before linking CAD references into Revit. The project environment should define worksets, view templates, naming conventions, shared parameters and the appropriate component-family library.

2. 3d System Development

Sprinklers, pipework, fittings, valves, risers, hydrants and supports are modelled according to the verified design. Pipe sizes, elevations, system classifications and connection relationships should be represented consistently. Repetitive tasks may be supported by Dynamo scripts, but modelers should check connectivity, component orientation, support spacing and correspondence with the source drawings. Model detail should be sufficient for the intended coordination and fabrication use without creating unnecessary complexity.

3. Federation And Clash Resolution

The fire-fighting model is coordinated with architectural, structural and other MEP models. Clash tests should be configured to detect relevant hard clashes and clearance violations. Each issue should be reviewed for validity, assigned to a responsible party, resolved through an agreed change and checked again in the next coordination cycle. A clash-free report is meaningful only when the model scope, test rules and exclusions are documented.

4. Compliance Review And Documentation

The model and its documentation should be checked against the applicable project requirements and adopted editions of relevant standards. NFPA 13 addresses sprinkler systems; NFPA 14 addresses standpipe and hose systems; NFPA 20 covers stationary fire pumps; NFPA 24 addresses private fire service

mains; and NFPA 318 addresses semiconductor fabrication facilities. The exact applicability and edition of each standard must be confirmed with the authority having jurisdiction and the project's fire-protection engineer. BIM geometry by itself cannot prove hydraulic performance, water-supply adequacy or complete code compliance.

After coordination, Revit views, sheets, quantities and schedules can be generated from the model. Documentation should be checked against the approved design and include revision status. Where quantities or shop drawings are generated automatically, sample outputs should be reconciled with the model and design documents before issue.

5. Parameter Strategy And Family Development

A reliable model depends not only on the visible shape of each component but also on the information stored in its family and instance parameters. For a chiller-building fire-fighting model, a practical parameter set may include component tag, system name, nominal diameter, material, elevation, connection type, specification reference and model status. Where information is not available in the source documents, it should be marked as "to be confirmed" rather than inferred by the modeller. This avoids creating a false impression that the model contains verified engineering data. The parameter structure should be agreed before large-scale modelling begins so that schedules, filters and quality checks use consistent fields [4,7].

Family detail should be selected according to the model's purpose. Coordination models generally need sufficient geometry to identify interfaces and clearances, while fabrication-oriented models may require connection points, fitting dimensions, hanger locations and installation allowances. Excessively detailed geometry can slow model performance without improving decisions. Conversely, generic objects that omit critical connection or access dimensions may conceal installation problems. The project BIM execution requirements should therefore define the required level of development and information for each object category, rather than applying one level of detail indiscriminately to every component.

6. Hydraulic Design And Geometric Coordination Are Different Checks

One of the most important controls in fire-protection BIM is to distinguish the spatial model from the engineering design. Revit can represent pipe routes, nominal sizes, elevations, fittings and sprinkler locations, but a geometrically complete network is not automatically hydraulically adequate. Hydraulic design requires verified inputs such as hazard classification, design criteria, water-supply characteristics, pipe roughness, elevation differences and the applicable calculation method. Those inputs and the resulting calculations must be prepared or approved by qualified fire-protection personnel using the adopted standard and project requirements [10–14].

The model review should therefore use two linked but separate checklists. The coordination checklist covers spatial matters: clashes with beams and ducts, access to valves, sprinkler obstruction, support interfaces, installation clearances and consistency between model and drawings. The engineering checklist covers design matters: the suitability of the selected system, sprinkler coverage and spacing, required design criteria, water supply, hydraulic calculations, equipment selection and applicable code provisions. BIM can help organize evidence for both checklists, but any automated pass/fail result should state exactly which rule was tested and what information was available. Rules that require engineering judgement must remain subject to specialist review [2,3].

7. Risk-Based Coordination For A Semiconductor Chiller Building

Not all model conflicts have the same consequence. A pipe crossing a non-critical ceiling element may be less significant than a sprinkler head obstructed by a large item of plant, a valve that cannot be reached during an emergency, or a main route that interferes with equipment removal. A risk-based process should classify issues by safety relevance, operational impact, constructability and urgency. A useful issue record includes a unique identifier, location, screenshots or viewpoints, the affected disciplines, the responsible party, the agreed corrective action, due date and closure evidence. This approach turns clash detection from a list of geometric intersections into a managed decision process [7].

The coordination sequence should also reflect the physical priorities of the building. Major equipment envelopes, structural members, access routes and primary service corridors should be established before minor branches and supports are finalized. Fire-fighting routes must be coordinated with HVAC ductwork, cable trays, process piping, lighting, access platforms and maintenance zones. The team should verify both the installed condition and the space required to inspect, test, isolate or replace equipment. For critical utility facilities, maintainability is a design consideration: a layout that fits in a model but prevents safe operation or routine testing is not a satisfactory coordinated solution.

8. Model-Based Information Management And Revision Control

A federated model is useful only when its constituent files are current and aligned. The project team should define a common coordinate system, levels, file naming rules, model ownership, exchange frequency and revision status. Before a coordination meeting, each discipline should publish a checked model and identify changes since the previous issue. The coordination lead should record the model versions used for each clash run so that an issue can be reproduced and traced. Without this discipline, a clash report may compare files from different design stages and generate misleading findings. Teo et al. [7] emphasize that successful MEP coordination depends on management practices as well as software capability.

A common data environment or an equivalent controlled document process can support review, approval and traceability. The model should distinguish design intent, coordinated design, fabrication information and as-built status where those stages are required. Changes to pipe routes, sizes, elevations or equipment locations should be reflected consistently in model views, schedules and issued drawings. When information is exchanged through IFC or other neutral formats, the team should test whether object identifiers, dimensions, system classifications and required properties survive the transfer. Interoperability should be assessed with representative test files rather than assumed from the availability of an export command. Information-management principles such as those described in ISO 19650-1 can provide a framework for defining information requirements, exchanges and responsibilities [15].

9. Use Of Dynamo And Rule-Based Automation

Dynamo can be useful for repetitive tasks such as applying parameter values, checking for missing fields, placing repeated supports from approved rules, generating model audit lists and preparing schedules. The greatest value is often achieved by automating predictable administrative operations while keeping design decisions under professional control. Before a script is used on the project model, it should be tested on a small sample, checked against known cases and documented with its inputs, assumptions and expected outputs. A script should also provide a report of skipped or failed objects rather than silently ignoring them. Automation can amplify an error as efficiently as it can repeat a correct operation, so independent checks are essential [4,7].

AI-assisted drawing recognition and automatic sprinkler-layout research suggest possible future support for converting legacy drawings and reducing repetitive placement work [1,8]. However, recognition errors can arise from unclear linework, overlapping symbols, inconsistent layers, incomplete dimensions and drawing revisions. A recognized line or symbol should not be treated as a verified BIM object until it has been reconciled with the source drawing and design intent. Similarly, automatically generated sprinkler locations do not by themselves demonstrate that the pipe network is connected, hydraulically adequate or compliant with every relevant rule [1,3].

10. Fire-Protection Standards And Project-Specific Applicability

Standards should be selected by the project fire-protection engineer and authority having jurisdiction, taking account of the facility type, adopted regulations, contractual requirements and applicable editions. NFPA 13 addresses sprinkler systems; NFPA 14 addresses standpipe and hose systems; NFPA 20 addresses stationary fire pumps; NFPA 24 addresses private fire service mains; and NFPA 318 specifically addresses protection of semiconductor fabrication facilities [10–14]. NFPA 318 includes provisions relevant to fire protection and hazards associated with semiconductor fabrication environments, but its applicability to a

particular chiller building must be determined from the project scope and the authority's requirements [14].

A BIM compliance matrix can help map each applicable requirement to its evidence source, responsible reviewer and status. For example, the matrix may identify whether a requirement is checked through a model view, a calculation, a manufacturer's data sheet, a design narrative or an authority approval. It should not imply that every requirement can be verified from geometry. The standard edition, amendments, local building and fire regulations, and project specifications should be recorded in the design basis. This is especially important because standards are periodically revised and an outdated checklist can produce a confidently documented but incorrect result.

11. Documentation, Handover And Operational Value

Once the design and coordination reviews are complete, the model can support the production of coordinated plans, sections, details, schedules and quantity summaries. These outputs should be checked against the approved design before issue. Sample checks should compare pipe sizes, component counts, tags and elevations between the model and the drawing set. Model-generated quantities may support procurement and cost review, but they should not be treated as final quantities without agreed measurement rules and verification. BIM and value-engineering studies indicate that structured model information can assist design review and cost-related decisions, although benefits depend on model quality and project processes [5].

Where the project requires an as-built or handover model, the information should be updated from verified site records and approved changes rather than simply relabelling the design model as "as built." Useful handover data may include equipment identifiers, valve locations, manufacturer information, maintenance instructions, inspection requirements and links to approved documents. The appropriate information level should be agreed with the owner and facility team. A model that contains excessive unverified data is less useful than a smaller, accurate dataset that supports inspection, testing, isolation and maintenance.

12. Implementation Risks And Quality Assurance

Common implementation risks include inaccurate or outdated CAD backgrounds, inconsistent units and coordinates, missing design inputs, unsuitable component families, over-detailed models, unreviewed automation and unclear responsibility for issue closure. These risks can be reduced through a staged quality-assurance process. At minimum, the team should conduct an initial drawing audit, a model setup review, periodic discipline checks, a federated coordination review, a final documentation audit and a recorded engineering compliance review. Each stage should have defined acceptance criteria and a named reviewer.

Quality assurance should be evidence-based. A model review log can record the date, model version, checks completed, exceptions, responsible person and approval status. Changes made after approval should trigger targeted rechecks of affected systems and documents. The review should also preserve unresolved items and assumptions in a visible register. This is preferable to treating a model as complete merely because it opens without errors or produces a clash report with few remaining items. A disciplined review process supports traceability and helps prevent visual completeness from being confused with design approval.

III. LITERATURE-BASED DISCUSSION FOR INDUSTRIAL UTILITY BUILDINGS

The literature points to a complementary rather than a single-tool solution. Fire-safety reviews describe BIM as an environment for sharing spatial and asset information, while also noting that specialist analysis may remain outside the authoring model [2]. Practitioner perspectives on sprinkler design similarly identify visualization and conflict detection as useful capabilities, but indicate that code-specific decisions are not fully automated [3]. Research on MEP modelling demonstrates how structured object information and repeatable modelling methods can improve the consistency of model production [4]. Together, these findings suggest that the main value of BIM is achieved when it links design information, spatial coordination and review evidence without treating the model as a substitute for engineering calculations.

For a semiconductor chiller building, this distinction matters because the fire-fighting network is only one part of a tightly packed utility environment. The model must coordinate with structural framing, chillers, pumps, electrical distribution, cable trays, ventilation, process services and maintenance access. A model may reveal that a pipe physically fits between two services, yet that route may still be unsuitable if it blocks equipment removal, complicates valve operation or creates an unacceptable obstruction to sprinkler discharge. Therefore, coordination rules should include operational access and maintainability alongside simple object intersection tests. The review by Teo et al. [7] also emphasizes that management practices, sequencing and the handling of irrelevant clashes influence the value of coordination technology.

Automation should be evaluated in the same cautious way. A script that places supports at a defined interval may save repetitive effort, but only if the interval and support conditions have been established by the responsible designer and are suitable for the pipe type, loading and project specification. A script that checks for missing parameters can improve data completeness, but it cannot determine whether the underlying value is technically correct. Similarly, a drawing-recognition model may identify likely pipe lines or symbols but can misinterpret crossing lines, revision clouds or low-resolution scans. The appropriate workflow is therefore "automate, inspect, approve": automation produces a candidate result, validation checks it against known inputs, and a responsible person approves the result before it is used for design or construction [1,4,8].

The evidence base also cautions against making unqualified productivity claims. MEP coordination studies report benefits from BIM-led approaches, but results depend on the project setting, the coordination strategy and the comparison baseline [7]. A chiller-building pilot should therefore measure both effort and quality. For example, a reduction in modelling hours would be of limited value if the model contained more unresolved issues or if additional manual checking was required later. Equally, a larger number of clashes found during early modelling may indicate improved detection rather than poorer design. The evaluation should report the number of valid issues by severity, the stage at which they were identified, the proportion closed before construction and the time spent resolving them.

1. Illustrative Coordination Scenarios

Scenario A—pipe route crossing a structural beam. A clash tool may flag a sprinkler main intersecting a beam. The team should first confirm the coordinate alignment and whether the intersection is real. The issue is then referred to the relevant designers to determine an acceptable reroute or other engineered solution. The fire-protection designer must confirm that any route change preserves the required system design and hydraulic performance. The model should not automatically shift the pipe simply to remove the clash.

Scenario B—sprinkler head close to equipment. A 3D view can help identify potential obstruction from a chiller, cable tray or duct. The team should compare the actual equipment envelope and sprinkler position with the applicable design criteria and standard. A visual adjustment may be proposed, but the final location requires review of coverage, spacing and obstruction rules by the qualified designer. This scenario demonstrates why a clash-free model is not synonymous with a compliant sprinkler layout [3,10].

Scenario C—valve or equipment access is blocked. A valve may have no geometric intersection with nearby objects yet still be difficult to operate or maintain. The coordination review should examine approach space, access platform requirements and the expected maintenance task. The issue can be documented with a model viewpoint and an agreed minimum access envelope, where defined by the project. This kind of issue may be missed by clash tests that only compare solid geometry, so a dedicated clearance review is needed.

Scenario D—model and drawing revisions disagree. A revised equipment layout may be received after the fire-fighting model has been coordinated. The team should confirm that all linked files have the correct revision, rerun the affected clash tests and check related sheets and schedules. The change should be recorded in the issue register, including the source revision and the model version used for closure. This reduces the risk of an old drawing being issued from a newer model or vice versa.

2. Proposed Model Quality Gates

A practical project can introduce five quality gates. Gate 1, source validation, checks drawing status, units, coordinates, levels and design inputs. Gate 2, model integrity, checks family suitability, parameter completeness, system assignment and pipe connectivity. Gate 3, interdisciplinary coordination, checks clashes, clearance zones and maintenance access against current discipline models. Gate 4, engineering verification, records the review of hydraulic calculations, design criteria and relevant standards by the responsible professionals.

Gate 5, issue and handover, checks that drawings, schedules, revision information and any required asset data agree with the approved design. Passing one gate should not be interpreted as automatically passing the next.

These gates can be recorded in a concise quality register with columns for requirement, evidence, responsible role, status, date and comments. The register provides a transparent record of what was checked and what remains open. It also helps distinguish model authoring tasks from engineering approval tasks. The proposed gates are a process recommendation derived from the literature synthesis; they have not been tested as a completed project procedure in this paper. Their effectiveness should be assessed in a pilot project and refined according to the owner's requirements, project risk and local approval process.

3. Future Research Priorities

Future studies should test the proposed workflow in more than one industrial utility building and report the project context in enough detail for comparison. Relevant contextual variables include building size, density of installed equipment, number of participating disciplines, maturity of the source drawings, modelling experience, required level of development and the adopted coordination process. Without this information, results from one project cannot be generalized reliably to another facility. A transparent baseline should document how the 2D workflow was performed, what tasks were included in the comparison and whether time spent on model validation and issue management was counted.

A second research priority is linking geometry with engineering evidence. A model-based workflow could associate sprinkler and pipe objects with calculation references, design criteria, approval status and the applicable standard clauses. Such links would improve traceability, but they should not imply that a model object itself proves compliance. Future systems should clearly identify which checks are automated, which require input from external calculation software and which require expert judgement. Any automated compliance function should be validated against reviewed test cases and should preserve a record of the rule version, input data and outcome.

Third, future research should evaluate the reliability of automated drawing interpretation and layout generation. Suitable measures include precision and recall for component recognition, the percentage of recognized objects accepted after review, pipe-network connectivity, the number of incorrectly inferred dimensions and the amount of manual correction required. For AI-generated sprinkler layouts, assessment should extend beyond head locations to include connected pipe routing, obstruction review, hydraulic design and compliance with the project's adopted requirements. These measures would provide a more complete picture than reporting only the time required to generate a preliminary layout [1,8].

Finally, studies should examine interoperability and operational handover. A coordinated model may be exchanged between authoring, clash-detection, calculation and facility-management systems, but data can be lost or reinterpreted during exchange. Research should test whether system classifications, identifiers, dimensions, revision history and asset attributes remain consistent across the tools used. Post-construction evaluation could then investigate whether the handover model helps facility personnel locate valves, plan inspections and manage maintenance records. These outcomes would extend evaluation beyond design-stage efficiency and connect model quality to the long-term needs of a critical utility facility.

IV. CRITICAL SYNTHESIS AND RESEARCH GAPS

The reviewed literature indicates four recurring findings. First, BIM improves spatial visualization and offers a shared reference for multidisciplinary coordination [2–4]. Second, automation can accelerate repetitive modelling and drawing interpretation, but its reliability depends on structured inputs, well-defined rules and validation [1, 4, 9, 10]. Third, model-based coordination can reveal conflicts earlier than workflows that rely only on separate 2D views, but the usefulness of clash results depends on the quality and currency of all linked models. Fourth, automated code checking remains incomplete for several nuanced fire-protection requirements, meaning specialist engineering review is essential [3].

A key gap is the limited evidence focused specifically on fire-fighting BIM workflows for semiconductor chiller buildings. Such spaces combine dense MEP services, critical cooling equipment, strict operational constraints and high consequences of fire-related disruption. More case studies are needed to quantify modelling effort, clash severity, revision frequency, documentation accuracy and coordination outcomes using a consistent baseline.

A second gap concerns evaluation metrics. Claims of efficiency should be supported by recorded modelling hours, number and type of clashes, percentage of issues resolved before construction, quantity deviations, drawing revision counts and the time required to produce schedules. A third gap is the distinction between geometric coordination and design validation. Future workflows should connect BIM data to documented hydraulic calculations, obstruction checks and rule-based code verification, while retaining professional approval.

Finally, interoperability remains important. Exchange formats and shared data structures can support collaboration between authoring, coordination, analysis and facility-management tools. However, data transfer must preserve identifiers, dimensions, system relationships and revision status. OpenBIM and model-based issue-management practices may improve continuity across project stages when implemented with clear information requirements.

1. Recommended Evaluation Framework

For a project-specific assessment, the proposed workflow can be evaluated against the original 2D-based process using a consistent scope and documented assumptions. Useful indicators include:

- Modelling productivity: person-hours required to create and revise the model.
- Geometric quality: number of valid clashes, clash severity and proportion resolved before issue.
- Information quality: completeness of component parameters, connectivity and drawing-to-model traceability.
- Documentation quality: agreement between model quantities, schedules, coordinated drawings and approved design documents.
- Compliance evidence: checklist completion for applicable standards and records of engineering review.
- Rework potential: recorded design changes attributable to coordination issues, where comparable project data are available.

The comparison should avoid presuming a positive result. Benefits should be reported only after measurements are collected. Any reduction in modelling time or clashes should be tied to the project scope, model maturity, team experience and baseline method.

2. Limitations

This paper is a narrative review informed by the literature cited in the project synopsis and does not report a completed BIM implementation or independently measured project outcomes. The performance of Revit, Navisworks, Dynamo or AI-based tools depends on software versions, model quality, team practices and project requirements. Standards are periodically revised; therefore, the applicable editions and local regulations must be verified before design approval. The review should not be interpreted as a substitute for fire-protection engineering, hydraulic calculations or approval by the authority having jurisdiction.

V. CONCLUSION

BIM provides a useful framework for developing and coordinating fire-fighting systems in complex industrial facilities such as semiconductor chiller buildings. A structured conversion from 2D AutoCAD drawings to a coordinated 3D Revit model can improve visualization, support multidisciplinary clash detection and enable consistent model-based schedules and drawings. Automation through Dynamo may reduce repetitive effort, while coordination tools can help identify spatial conflicts before installation. Nevertheless, successful implementation depends on verified source information, disciplined model management, meaningful clash classification and documented review against applicable fire-safety standards. The most important research opportunity is to validate this workflow in a real project and quantify its effects on modelling time, coordination quality, documentation accuracy and rework. BIM should complement—not replace—engineering judgement and formal fire-protection verification.

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