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Master in

Building Information Modelling



European Master in
Building Information Modelling

Integrating Building Openings into BIM Workflow Management for
Optimal MEP Detailed Design: A Study in Building Construction

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SOMMARIO

Questa tesi esplora l'integrazione delle forometrie degli edifici all'interno del framework Building Information Modelling (BIM) per la progettazione dettagliata MEP nel contesto della costruzione di impianti industriali. Comprende un'approfondita revisione della letteratura, fornendo una panoramica del BIM nel settore dell'architettura, dell'ingegneria e delle costruzioni (AEC), sottolineando l'importanza della progettazione MEP e indagando sulle metodologie di coordinamento. Lo studio presenta anche un caso studio completo con l'obiettivo primario di sviluppare un flusso di lavoro ottimizzato per una migliore gestione delle forometrie destinate alle apparecchiature MEP. Il caso studio si concentra sul miglioramento della gestione delle forometrie all'interno di un progetto di costruzione di un impianto industriale. L'indagine valuta l'uso di strumenti e tecniche di automazione per integrare perfettamente queste aperture nel flusso di lavoro BIM. I risultati evidenziano diversi vantaggi, tra cui un migliore coordinamento, una riduzione delle rilavorazioni, una maggiore efficienza nella progettazione MEP e la possibilità di automatizzazione. Inoltre, lo studio esplora il miglioramento del coordinamento sia all'interno che tra i dipartimenti esterni. La tesi si conclude riassumendo i suoi contributi al campo e presentando raccomandazioni per le future direzioni di ricerca. Questo lavoro fornisce un contributo sostanziale al progresso dello stato dell'arte in merito alla progettazione dettagliata BIM e MEP, affrontando una notevole lacuna nella letteratura relativa all'integrazione delle forometrie degli edifici nel flusso di lavoro BIM per la progettazione dettagliata MEP nel settore della costruzione di impianti industriali.

Parole chiave: Automatizzazione, BIM, Coordinamento, Forometrie, flusso di lavoro, MEP, MagiCAD, Placeholder Provisions, Revit.

ABSTRACT

This thesis explores the integration of building openings within the Building Information Modelling (BIM) framework for MEP detailed design in the industrial plant construction context. It encompasses a thorough literature review, providing an overview of BIM in the Architecture, Engineering, and Construction (AEC) industry, underlining the significance of MEP design, and investigating coordination methodologies. The study also features a comprehensive case study with the primary aim of developing an optimized workflow for better managing cutouts intended for MEP equipment. The case study focuses on improving the management of cutouts within an ongoing industrial plant construction project. The investigation assesses the use of automation tools and techniques to seamlessly integrate these openings into the BIM workflow. The outcomes highlight several advantages, including enhanced coordination, reduced rework, increased efficiency in MEP design, and the potential for automation. Furthermore, the study explores the improvement of coordination both within and among external departments. The thesis concludes by summarizing its contributions to the field and presenting recommendations for future research directions. By addressing a notable gap in the literature related to the integration of building openings into the BIM workflow for MEP detailed design in the industrial plant construction sector, this work makes a substantial contribution to advancing the state of BIM and MEP detailed design.

Keywords: Automatization, BIM, Cutouts, Coordination, MEP, MagiCAD, Placeholder Provisions, Revit, Workflow.

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1. INTRODUCTION

1.1. Background (Scope of Work)

BIM integration has become a revolutionary force in the constantly shifting landscape of the Architecture, Engineering, and Construction (AEC) Industry. BIM offers a multidimensional digital approach to design, construction, and facilities management, revolutionizing project delivery and collaboration. This paradigm shift in the AEC industry has had a particularly profound impact on the industrial plant construction sector.

Industrial plant building projects face several difficulties because of their scale and complexity. The successful completion of these projects depends on careful planning and seamless integration of a variety of systems, structures, and components. Mechanical, Electrical, and Plumbing (MEP) systems are a key component of these intricate systems.

Understanding that automation involves introducing computers into a process to reduce human involvement, and keeping in mind that computers operate based on specific rules. This process of evaluating construction projects can be easily translated into a computer-based process. Here, the requirements set for a project, like its design criteria, are translated into a computer language, and the assessment is carried out digitally. Using Building Information Modeling (BIM) as the tool for digitalizing construction, this translation of design assessment becomes a rule-based model check, essentially making it a routine use of BIM. BIM provides a wealth of data, making it highly valuable for project analysis. Consequently, code-checking can be described as the procedure for examining the model to ensure it complies with predetermined specifications, performance standards, or safety codes (BIME Initiative, 2022).

One of the critical aspects of industrial plant construction is the incorporation of building openings, such as doors, windows, and openings for equipment and utilities, into the BIM workflow. These openings are essential for proper coordination and functionality of MEP systems. However, challenges arise when design delays or last-minute changes occur, necessitating adjustments to the openings. This can pose significant difficulties, including increased costs, rework, and time-consuming modifications, especially when the walls and slabs have already been cast. To tackle these difficulties, using BIM methods becomes crucial. BIM offers a digital structure that not only enables detailed modeling of MEP systems but also provides an advanced way to handle openings. With BIM, these openings can be accurately portrayed, synchronized, and included in the project's overall design. This thorough approach guarantees that everyone involved, from designers to contractors, has access to precise and current information about openings, which lessens the chances of expensive mistakes and interruptions. This thesis project aims to address these challenges by investigating the integration of building openings into the BIM workflow for MEP detailed design in the industrial plant construction sector. The research will explore the use of automation tools and techniques to streamline the coordination and communication processes between design departments and the fabrication team. By proposing practical solutions, this study seeks to enhance construction efficiency, cost-effectiveness, and overall project success.

By conducting an in-depth case study, this research will offer significant insights into the advantages of incorporating building openings. These benefits encompass enhanced coordination, minimized rework, improved efficiency in the MEP design phase, and the potential for automation. This thesis project seeks to advance the current standards in BIM and MEP detailed design practices, aiming to enrich the knowledge base within this field and provide valuable support to professionals engaged in industrial plant construction.

1.2. Significance of the Study

- Streamlining Workflow Management:



Figure 1 - Streamlined Process Requirements (Informatica, 2019)

Within the organization, the need for a well-defined workflow to manage the cutouts process is paramount. The study addresses this essential requirement, aiming to establish a structured and efficient approach to cutout management.

- Optimizing Resource Allocation:

Currently, the organization allocates an excessive number of staff and significant man-hours on managing the cutouts process. It is crucial that these resources are used wisely, and that the procedure is optimized to reduce the number of resources needed. The goal of the study is to implement this crucial change, which will save resources and promote more efficient operations.

- Project Complexity and Multi-Department Involvement:

Given the vast scale and industrial nature of the construction projects undertaken, the involvement of numerous departments and stakeholders in the engineering, design, procurement, and construction phases is inevitable. The cutouts, being a fundamental component, become a critical concern if not managed effectively. Errors or changes in the cutout specifications, once provided to precast panel vendors or contractors responsible for cast-in-situ components, can lead to significant challenges. The need for costly and time-consuming revisions, including the destruction of panels and concrete structures, underscores the criticality of a well-managed cutouts process. The study aims to mitigate these issues and ensure that cutout specifications are accurate and manageable from the outset.

- **Cost Efficiency and Time Optimization:**

Proper cutout management from the initial design stages leads to substantial cost reduction and time savings. By ensuring accurate cutout specifications before providing them to vendors or fabricators, the organization can prevent costly rework, alterations, and demolitions of precast panels or cast-in-situ components. This proactive approach minimizes expenses and streamlines project timelines, enhancing overall cost-efficiency and efficiency.

- **Transitioning from Traditional to Streamlined Methods:**

The study assumes even greater importance in the context of the organization's transition from traditional, 2D-based coordination methods to more streamlined, 3D-oriented approaches for cutout management. The adoption of modern, three-dimensional inputs and outputs is essential to keep pace with industry advancements and to ensure a more efficient and effective cutout management process.

1.3. Objectives

- Evaluate the current openings management process, establish the AS-IS process model, and optimize it to formulate the TO-BE process model.
- Develop a strategy for obtaining 3D input data on openings from all relevant departments.
- Implement automation to generate placeholder provisions representing openings, enabling departments to contribute input for opening creation.
- Automate the process of creating openings in models using input data from placeholder provisions.
- Enhance intra-departmental coordination, especially in the clash detection process for identifying opening-related conflicts.
- Provide 3D outputs exclusively to the relevant departments.
- Create a comprehensive organizational work instruction document for future activities related to openings.

1.4. Brief Description by Chapter

The thesis is structured into five main chapters, which are outlined as follows:

- **Chapter 1** offers an introduction to the research, outlining the scope of the study, its significance, and the specific objectives of the thesis.
- **Chapter 2** explores a comprehensive review of existing literature, focusing on BIM within the AEC industry. It covers BIM methodologies, practices in design coordination related to MEP, and the challenges and obstacles encountered in adopting BIM in the AEC sector.
- **Chapter 3** lays out a general methodology and a set of steps to be followed during the case study, aimed at achieving the desired outcomes.

- **Chapter 4** provides an in-depth description of the procedural steps involved in illustrating the TO-BE process map, using a case study as an illustrative example.
- **Chapter 5** serves as a summary, summarizing the key findings, acknowledging limitations, and offering future recommendations for more effective management of openings in Industrial plant projects.

2. LITERATURE REVIEW

2.1. Overview of BIM in AEC Industry

- **BIM Methodologies**

AEC Industry has entered a transformative era because to BIM approaches, which have profoundly changed how these enormous facilities are planned, built, and operated. Virtual collaboration, clash detection, construction document development, conceptual design support, planning and visualization, cost estimating, operations, and maintenance are just a few of the crucial elements that these techniques cover.

The core of BIM techniques is virtual collaboration, which enables smooth and accurate cooperation amongst a wide range of stakeholders involved in facility design. A common virtual model unites owners, architects, engineers, contractors, subcontractors, and suppliers, facilitating communication and decision-making procedures. In addition, clash detection plays a critical role in identifying and resolving conflicts within the complex network of building systems and components by leveraging the three-dimensional capabilities of BIM. This proactive strategy reduces mistakes and rework during construction, saving a significant amount of money and time. (United BIM, 2023)

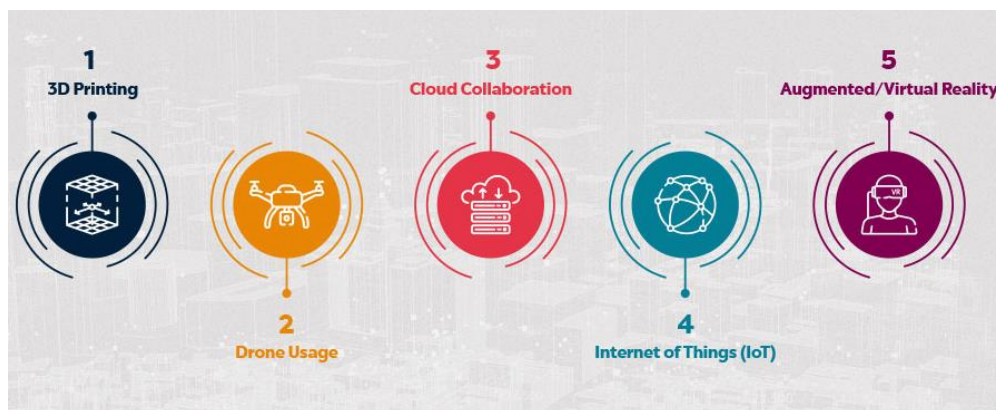


Figure 2 - BIM Trends Driving the AEC Industry (United BIM, 2023)

The creation of construction documents, made possible by BIM's ability to build comprehensive and interconnected documents that include precise drawings, procurement specifications, and essential project data, is another tenet of BIM methodology. As the project progresses, these papers continue to be dynamic and updated in real-time to guarantee stakeholder alignment. Additionally, BIM approaches support conceptual design strongly by leveraging virtual models to facilitate choices analysis and value engineering. Stakeholders gain from three-dimensional visualization because it helps them make well-informed decisions and choose the most economical building design. (Khemlani & Hein, 2016)

BIM approaches also provide planning and visualization services, enabling stakeholders to create accurate renderings and envision the facility's appearance prior to the start of construction. Effective communication and precise pre-construction planning are fostered by this capacity. BIM software incorporates cost estimating functions, automating the extraction, and updating of material quantities,

and ensuring accurate cost estimation and budgeting from the start of a project to its conclusion. Finally, BIM models serve a crucial role in operations and maintenance, improving efficiency and reducing operating costs. These models are enhanced with crucial data on the facility's geometry, spatial relationships, quantities, qualities, and schedules of building elements. (Azhar & Ritcher, 2019)

• **Importance of MEP Design and Coordination**

Consider a construction job as a challenging puzzle with numerous pieces that must all exactly fit together. MEP coordination and design are like the deft puzzle-solving techniques that guarantee the pieces fit together perfectly. We prevent conflicts and hiccups during construction by synchronizing Mechanical, Electrical, and Plumbing (MEP) systems. This translates to easier progress, fewer errors, and ultimately a more productive and economical project. MEP coordination orchestrates the different systems within a building, ensuring they operate without a hitch. (Yarmahammadi & Ashuri, 2015)

MEP coordination has advantages that extend beyond the construction period and improve the project. It makes sure everything stays working like a well-oiled machine when the building is finished. Less downtime and lower maintenance costs are the result of clear documentation, simple equipment access, and effective troubleshooting techniques. Electrical codes and other safety rules are followed, protecting both the passengers and the investment. Essentially, careful MEP coordination improves the project's overall quality by ensuring that systems work as planned not only during construction but also for many years to come. (Yarmahammadi & Ashuri, 2015)

Project Phase	Recommended Best Practices
<i>Schematic Design</i>	<ul style="list-style-type: none"> Establish a detailed workflow for coordination process Clarify the roles and responsibilities that the general contractor and trades must take on through modeling and coordination processes
	<ul style="list-style-type: none"> Break down the project into smaller sub-projects based on the project size, MEP system density, and bid package priorities Define the extent to which the models should be detailed and coordinated
<i>Design Development</i>	<ul style="list-style-type: none"> Utilize the same software platform among coordination team to avoid interoperability issues Invest as much effort as possible on developing BIM models (Models with higher LOD allow the coordination team to address micro level conflicts.)
	<ul style="list-style-type: none"> Make sure modelers/engineers have the required expertise on the division they are handling and are familiar with local building codes. Make sure coordination team members are competent in both coordination and modeling Initiate coordination by trades with larger components and continue to the ones with smaller equipment
<i>Construction Documents</i>	<ul style="list-style-type: none"> Identify high-priority and outstanding clashes before each meeting Categorize clashes that belong to similar geometrical units into clash batches Record and document discussions, ideas, and solutions during coordination meetings Hold weekly or biweekly meetings with designers to review issues that require immediate attention
	<ul style="list-style-type: none"> Ensure accuracy of 3D models and drawings for quantity take off Make sure subcontractors have in-house BIM capabilities so they can keep models up-to-date
<i>Bid</i>	<ul style="list-style-type: none"> Check constructability of the developed shop drawings Provide field staff with quick access to the most updated models Record and report change orders and RFIs in an organized format
<i>Construction Administration</i>	<ul style="list-style-type: none"> Check constructability of the developed shop drawings Provide field staff with quick access to the most updated models Record and report change orders and RFIs in an organized format

Figure 3 - Recommendations to Improve Design Coordination (Yarmahammadi & Ashuri, 2015)

Technology is crucial to the landscape of contemporary construction. Building information modelling (BIM), one such technology innovation, is centered on MEP coordination. Consider BIM to be the construction project's digital twin. It enables us to build an intricate virtual model with MEP systems. We can identify problems before they develop into expensive on-site concerns thanks to this early digital planning. In essence, MEP coordination becomes the key to maximizing the potential of BIM. It makes certain that the bigger building project's mechanical, electrical, and plumbing systems interact seamlessly, improving both efficiency and quality. These 3D models are created using software programs like Autodesk Revit, Bentley MicroStation, and Graphisoft ArchiCAD, which makes it easier to coordinate MEP systems in a BIM context (Autodek Revit, 2023). These tools allow us to visualize how different MEP components, such as ductwork, pipes, and electrical conduits, interact with each other within the building's design. They play a critical role in early clash detection and resolution, reducing costly rework during the construction process. In essence, these software tools act as the architect's canvas, where the intricate details of MEP systems are painted, ensuring a harmonious integration within the broader construction project. (Motamedi & Hammad, 2019)

- **Best Practices and Standards**

To achieve seamless integration and operational effectiveness in the challenging area of coordinating MEP systems within industrial plant projects, a strong foundation of industry standards and best practices has formed. The ideas and procedures regulating MEP cooperation in this situation are comprehensively covered by the standards discussed.

The use of BIM, a fundamental strategy that facilitates the integration of MEP systems into the overarching plant design, is crucial to this coordination effort. BIM makes collaboration possible by enabling the production of a digital model that includes all MEP components. This digital representation improves visualization while also making clash detection easier, saving time and money. BS 1192:2007 and PAS 1192-2:2013, which provide guidelines for information exchange during the design and construction phases, respectively, as well as practices for the collaborative production of architectural, engineering, and construction information, are important BIM standards that support collaboration. (Love, Mandal, & Li, 2017)

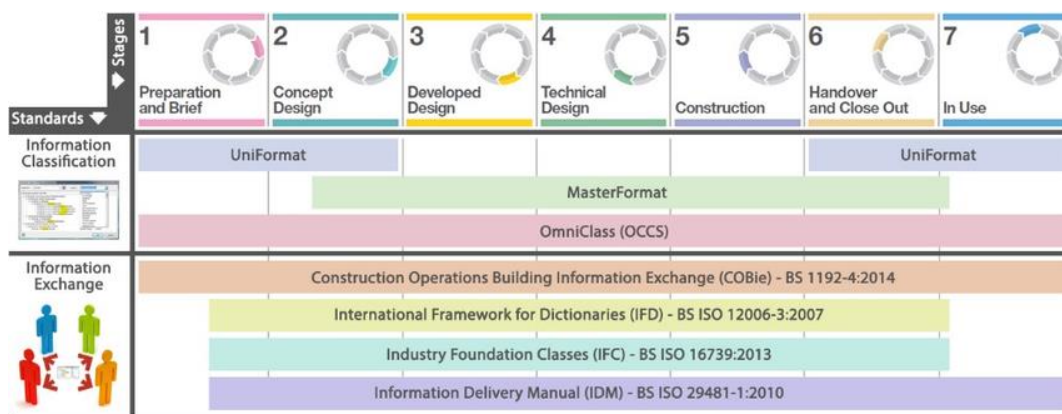


Figure 4 - Conceptual Information Standards Framework by RIBA Project Phase (Lea, Ganah, Goulding, & Ainsworth, 2015)

Regular coordination meetings that bring together MEP designers, contractors, and stakeholders complement the role of BIM standards. To ensure effective coordination and integration, these sessions act as a critical platform for discovering and resolving disputes or clashes among various MEP systems. Parallel to this, 3D MEP modeling tools improve the visibility of electrical, ducting, and equipment components while also streamlining system routing and proactively spotting potential conflicts. Standardized MEP design principles, like those in ASHRAE, offer a systematic framework for uniform equipment selection, installation techniques, and quality control procedures in addition to these practices. They encourage standardization in the design and installation of MEP systems. Additionally, the crucial data format and standard known as COBie (Construction Operations Building Information transmission) enables smooth information transmission between design, construction, and facility management teams. This format specifies the precise information needs and format standards for transmitting asset data at various project lifecycle stages. (Lea, Ganah, Goulding, & Ainsworth, 2015)

The US National Building Information Modeling Standard (NBIMS), which also covers information interchange, data formats, and interoperability within the country, is the final set of standards and recommendations for BIM implementation. Together, these standards create a shared framework and vocabulary for communication, ensuring that everyone involved in the project has the same objectives and uses the same procedures and information formats. They use this to improve communication, decrease mistakes, and ultimately increase project efficiency. (Succar, 2018)

- **Technological Advances**

The coordination of MEP systems has seen a significant transition recently, as seen in the building industry. Most of these developments can be attributable to the growing use of BIM and 3D modeling methods. As a game-changer, BIM provides a collaborative platform that enables architects, engineers, and contractors to synchronize MEP systems well in advance of the start of construction. By utilizing virtual models, BIM makes it easier to discover clashes and coordinate their resolution, thereby reducing conflicts and speeding up the construction process. It also improves spatial coordination through immersive 3D imagery, offering a more all-encompassing method of MEP system coordination. (Chen, Lu, Wang, & Zhang, 2015)

The seamless integration of MEP systems with structural and architectural components is another benefit of BIM. By ensuring alignment and minimizing interference, this integration efficiently gets rid of the need for pricey rework and project delays. The clash detection function of BIM is a useful tool for spotting and resolving future disputes. Beyond the building stage, BIM helps the development of intricate MEP models that include equipment specs, installation instructions, and extensive maintenance plans. Throughout a building's lifespan, this detailed information is still available, which greatly aids in efficient operation and maintenance procedures. Fundamentally, the development of BIM and 3D modeling has ushered in a new era of MEP coordination, making it a thorough, team-based, and forward-thinking process that is crucial to construction projects. (Chen, Lu, Wang, & Zhang, 2015)

In addition to revolutionizing MEP coordination, these developments have had a significant impact on many facets of the building industry. A centralized hub for information interchange and real-time collaboration made possible by BIM have eased communication between the various disciplines engaged in MEP design and installation, eliminated misunderstandings, and enhanced overall project

coordination. Additionally, BIM-driven 3D modeling has sped up the design and coordination of MEP systems, enabling more effective design iterations and reducing the need for pricey rework. As a result, the broad adoption of BIM and 3D modeling marks an important turning point in the construction industry's pursuit of improved efficiency and seamless coordination, notably in the area of MEP systems. (Succar, 2018)

- **Challenges and Barriers**

Several obstacles and problems stand in the way of the adoption of BIM in the Architecture, Engineering, and Construction (AEC) sector. These difficulties are frequently encountered in both the larger AEC context as well as the coordination of Mechanical, Electrical, and Plumbing (MEP) systems within industrial operations.

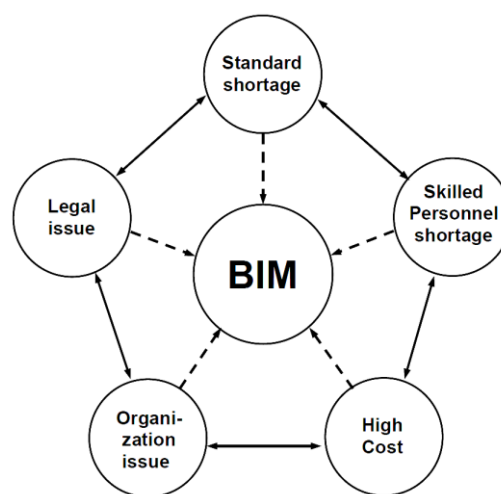


Figure 5 - Relationship Between Main Barriers (Liu, Xie, Tivendal, & Liu, 2015)

A frequent issue is resistance to change. Organizational resistance to the adoption of BIM methodologies as opposed to conventional processes and practices is possible. This resistance could be brought on by a reluctance to alter accepted procedures and workflows. Additionally, some firms are hesitant to commit resources up front because of the significant initial expenditure needed for BIM technology and training. Another major obstacle is interoperability problems. Different project stakeholders may utilize different software tools and platforms, which could cause issues with data interchange. This problem may impede effective information sharing and collaboration, which could reduce the effectiveness of the project. (Liu, Xie, Tivendal, & Liu, 2015)

Complexity is a common obstacle in industrial plant project contexts. These projects frequently involve complex MEP systems and several disciplines, which makes BIM implementation difficult. It can be difficult to keep BIM models current over the course of a project since as-built circumstances and design modifications must be regularly integrated. A lack of qualified staff experienced in BIM technology and its use in industrial plant projects might also obstruct its deployment. For efficient coordination and clash detection, particularly within MEP systems, qualified BIM professionals are required. (Liu, Xie, Tivendal, & Liu, 2015)

Organizations must foster a culture of change-readiness and make investments in technology and training if they are to overcome these obstacles and problems. To resolve interoperability problems, project stakeholders must work together and communicate effectively. Implementation can be sped up by the creation of precise BIM guidelines and standards tailored to industrial plant projects. Initiatives for ongoing education and skill development guarantee a pool of BIM experts who are qualified. Real-time collaboration and model updates are facilitated using cloud-based BIM platforms. In the end, a carefully thought-out and staged approach to BIM deployment can result in its successful integration into industrial plant projects, improving efficiency and coordination, with an emphasis on addressing these problems. (Liu, Xie, Tivendal, & Liu, 2015)

3. METHODOLOGY

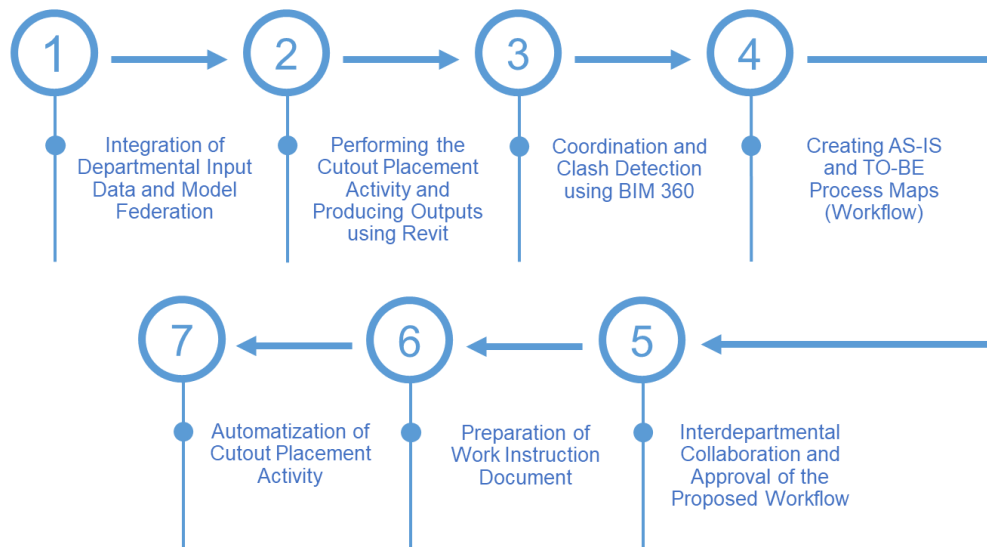


Figure 6 - Timeline for Activities

3.1. Integration of Departmental Input Data and Model Federation

- Define the Integration Scope:

Clearly outline the scope of data integration, including the types of inputs (3D models, 2D sheets) and the departments involved (Civil, HVAC, Plumbing, Electrical, Instrumentation, Health, and Safety).

- Collect Input Data:

Gather 3D models and 2D sheets from each department from BIM360 CDE, ensuring that the data is complete and up to date.

- Standardize Data:

Establish data standards and formats to ensure consistency and compatibility between different departmental inputs.

- Model Federation:

Use Revit's model linking functionality to integrate the 3D models from various departments with the architectural model. Ensure proper alignment and positioning of the linked models.

- Review and Validate Integration:

Collaborate with representatives from each department to review the federated model and verify that all departmental inputs are accurately integrated.

3.2. Performing the Cutout Placement Activity and Producing Outputs

- Identify the Relevant Building Systems:

Determine the specific systems (e.g., Civil, HVAC, Plumbing, Electrical, Instrumentation, Health, and Safety) that require cutouts and their respective design requirements.

- Utilize the Federated Model in Revit:

Use the Revit software to create a federated model that combines models from various into a single cohesive model.

- Place Cutouts in Clash Areas:

Using the federated model, place cutouts at locations where the building system elements clash with the structure, ensuring that the necessary clearances are maintained.

- Produce 3D views and 2D Sketches:

Generate 3D views and 2D sketches that illustrate the placed cutouts in the federated model, providing visual representations of the proposed solutions.

- Validate and Refine the Outputs:

Review and verify the produced 3D views and 2D sketches, ensuring that the placed cutouts are accurate and align with the design requirements.

- Iterate and Revise as Necessary:

Incorporate feedback from stakeholders, such as designers and construction professionals, and make any necessary adjustments to improve the accuracy and effectiveness of the cutout placements.

3.3. Coordination and Clash Detection using BIM360

- Define Coordination Objectives:

Clearly outline the goals and objectives of coordination and clash detection, such as identifying and resolving conflicts between building systems.

- Establish Coordination Protocols:

Define the communication channels, file exchange procedures, and collaboration methods to facilitate effective coordination among stakeholders.

- Utilize BIM360 Software:

Employ BIM360 or other similar collaboration platforms to host the project models, share information, and enable real-time collaboration among stakeholders.

- Conduct Clash Detection Analysis:

Use BIM360's clash detection functionality to identify clashes or conflicts between different building systems, highlighting areas where adjustments or modifications are required.

3.4. Creating AS-IS and TO-BE Process Maps (Workflows)

- Identify the Workflow Requirements:

Determine the scope and objectives of the AS-IS model and cutout management presentation, considering factors such as project size, complexity, and stakeholder needs.

- Collect Relevant Data:

Gather information about the existing workflow, including documentation, interviews, and observations, to understand the current state accurately.

- Analyze the Existing Workflow:

Evaluate the strengths, weaknesses, and inefficiencies of the current process, identifying areas for improvement and optimization.

- Develop the AS-IS model:

Create a visual representation of the existing workflow using process flowcharts, diagrams, or other suitable methods to document the sequence of activities and dependencies.

- Design the TO-BE Model:

Develop a new workflow model that incorporates the desired improvements and addresses the identified weaknesses in the existing workflow.

- Incorporate Recommendations:

Propose recommendations for improving the cutout management process, such as implementing automation tools, enhancing communication channels, or optimizing coordination among stakeholders.

3.5. Interdepartmental Collaboration and Approval of the Proposed Workflow

- Schedule Coordination Meetings:

Arrange meetings with representatives from each department to discuss the proposed workflow, its benefits, and potential challenges.

- **Present the Proposed Workflow to Relevant Departments:**

Share the details of the proposed workflow, including the objectives, processes, and expected outcomes, using visual aids, presentations, or workflow diagrams.

- **Address Concerns and Incorporate Feedback:**

Analyze the feedback received and address any concerns or questions raised, incorporating valuable suggestions and modifications into the proposed workflow.

3.6. Preparation of Work Instruction Document

- **Gather Information:**

Collect comprehensive details about the cutout management process, including steps, best practices, and key considerations.

- **Document Procedures:**

Provide detailed, step-by-step instructions for each task in the cutout management process by explaining the TO-BE model in complete detail.

- **Use Visual Aids:**

Enhance understanding by incorporating diagrams, images, or screenshots following the organization's document structure rules.

- **Review and Validation:**

Collaboratively review and validate the work instruction document for accuracy and completeness, incorporating feedback received during the process.

3.7. Automatization of Cutout Placement Activity

- **Define Objectives:**

Clearly state the goals of automating cutout placement, emphasizing efficiency, accuracy, and cross-platform compatibility.

- **Automate Cutout Placement in Revit:**

Develop, validate, and document Dynamo scripts tailored for Revit models. Provide comprehensive training to personnel on utilizing these scripts within Revit.

- Automate Cutout Placement in Tekla:

Automate the creation of cutouts for federated models, incorporating IFC files from departments using non-Revit software, and leveraging the Tekla environment as part of the process. Ensure compatibility with various file types, document the procedures, and provide training to personnel for effective implementation.

- Iterate and Refine Automation Methods:

Continuously improve both the Dynamo scripts and Tekla plugin automation method based on feedback and performance. Address any identified issues promptly.

- Documentation:

Create detailed documentation for both automation methods, including step-by-step instructions, configurations, and best practices. This documentation ensures easy implementation and serves as a reference for future projects.

- Implementation:

Deploy the respective automation methods in your projects, utilizing Dynamo scripts for Revit models and the Tekla plugin for federated models with diverse file types. Ensure smooth integration into the workflow.

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4. CASE STUDY

4.1. Organizational Structure and Departments

Within the organization, numerous departments participate in the design phase of large-scale industrial plant projects. Due to the project's substantial size, the work is divided among several departments where employees collaborate extensively to achieve the desired outcomes. This thesis report elaborates on the departments that play various roles in the cutout management process. These departments can be categorized into two primary types: core departments, which are internal units of the organization, and external consultants or subcontractors engaged by the building department for specific design tasks. Figure 7 provides a breakdown of the different departments involved.

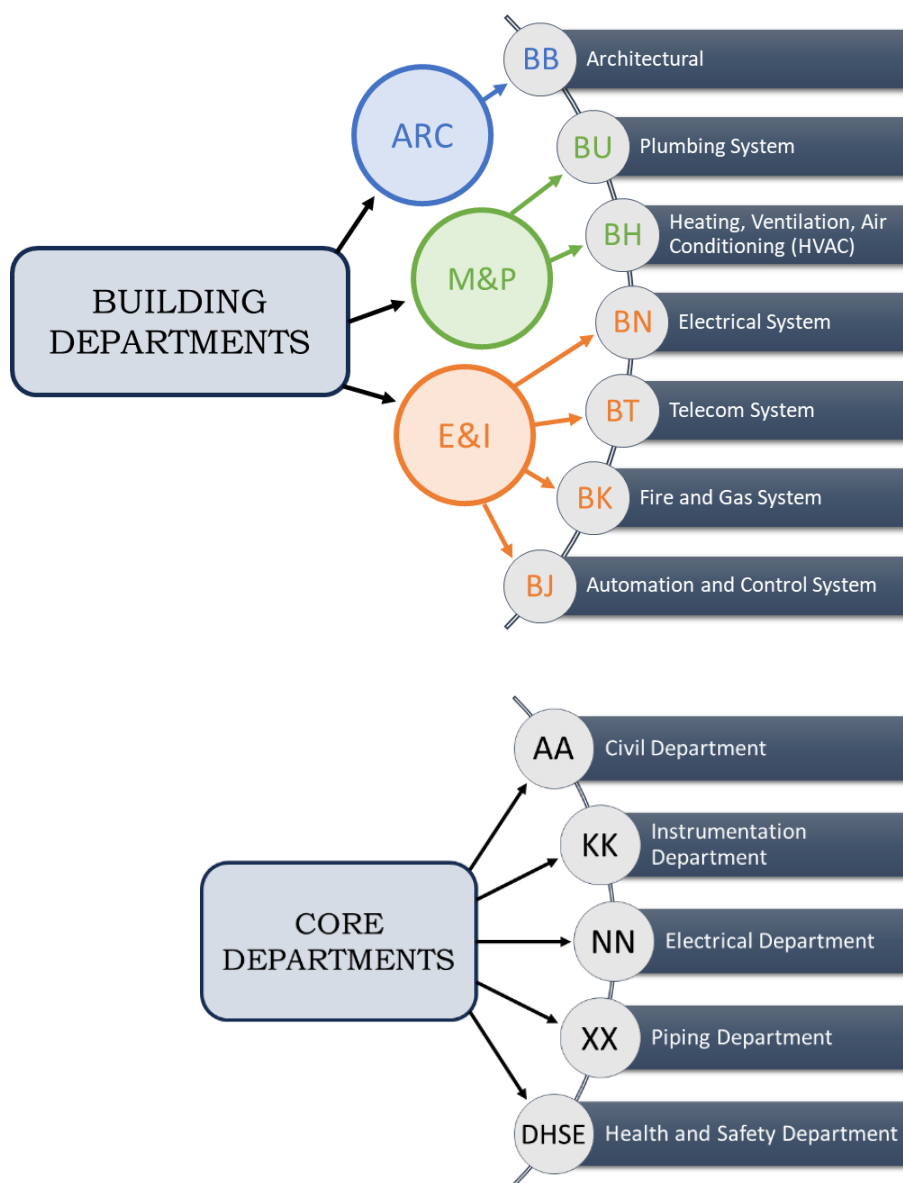


Figure 7 - Departmental Breakdown Structure

4.1.1. Building Departments

The Building department itself is one of the core department within the organization, collaborating closely with all other essential departments. This department encompasses all design and modelling aspects related to the architectural elements of the buildings. Figure 7 illustrates the composition of the Building department, which primarily consists of three subdisciplines: Architectural (ARC), overseen by the BB (Architectural department); Mechanical and Plumbing (M&P), further categorized into BU (Plumbing System) and BH (Heating, Ventilation, Air Conditioning System); and Electrical and Instrumentation (E&I), which is also subdivided into BN (Electrical System), BT (Telecom System), BK (Fire and Gas System), and BJ (Automation and Control System). These subdivided departments are considered external to the Building department, often requiring the engagement of external consultants or subcontractors to oversee their specific tasks.

4.1.2. Core Departments

The core departments of the organization primarily handle the design aspects of every part of the industrial plant, so their scope extends beyond just the buildings to encompass other critical plant structures. These core departments are the key departments of the organization, carrying out the major work of the project. They consist of the Civil department (AA), Instrumentation department (KK), Electrical department (NN), Piping department (XX), and Health and Safety department (DHSE). It's important to note that these abbreviations align with the organization's conventions.

4.2. BIM Process Workflow

To manage cutouts in the BIM process successfully, a structured workflow must be established that includes all the sequential tasks needed. The development of organized AS-IS (current state) and TO-BE (desired future state) process models is an essential phase in this approach. These models act as representations of the current and planned processes, making it easier to grasp the many procedures and identify opportunities for development and optimization.

Stakeholders may visualize a more successful approach by building and contrasting these two models, which will provide them with useful insights into the current flaws. Project teams can use it to find possible risks, evaluate the effects of changes, and come to wise conclusions that will optimize the entire workflow.

Overall, the careful development and utilization of these models serve as the foundation of an effective BIM process workflow, ensuring an organized and effective method of managing cutouts and improving the results of the project.

4.2.1. AS-IS Process Map

The AS-IS process map highlights the current procedures, resources, and possible problems in our cutout management process, which reflects its current state. It acts as a starting point for analysis and a benchmark for measuring the effectiveness of any improvements or modifications made in the future.

Figure 8 on the following page, depicts the AS-IS BIM process map for the management of Cutouts activity. Each step in the workflow is indexed to represent the type of activity involved. Additionally, the activities are numbered to facilitate easy reference and detailed explanation in subsequent chapters.

The BIM process workflow for managing cutouts in a building project involves several sequential activities. It starts with the Architecture department creating the building model (activity 1) and receiving 3D Revit files from various external consulting departments (activity 2), such as HVAC, Automation and Control System, Electrical System, Instrumentation, Plumbing, and Civil departments. The core departments provide additional 2D input sheets (activity 3) for piping, instrumentation, electrical systems, and design health and safety environment.

Next, manual drafting (activity 4) is carried out to organize and coordinate the input data, focusing on the precise location of cutouts. A federated model is then prepared (activity 5) by incorporating the linked 3D models. A general 3D model quality control check (activity 6) and a check for placeholders (activity 7) which indicate the location and type of cutouts are performed.

The process continues with the addition of openings using defined window families (activity 8), leading to multiple outputs. One output is a 3D model view (activity 9) created for vendors, specifically for pre-cast walls. Vendors utilize this view to update their 3D models accordingly and produce relevant 2D sheets (activity 13).

Another output consists of 2D sheets (activity 10), catering to the cast in-situ and pre-cast slab sections. These sheets are used by the Civil department to update their 3D models (activity 14) and provide the updated structural parts with the designated openings to the vendor (activity 17,20).

In summary, the BIM process involves a series of activities that begin with model creation and data input from various departments, followed by coordination, quality checks, and the generation of 3D and 2D outputs to facilitate effective communication and collaboration among stakeholders.

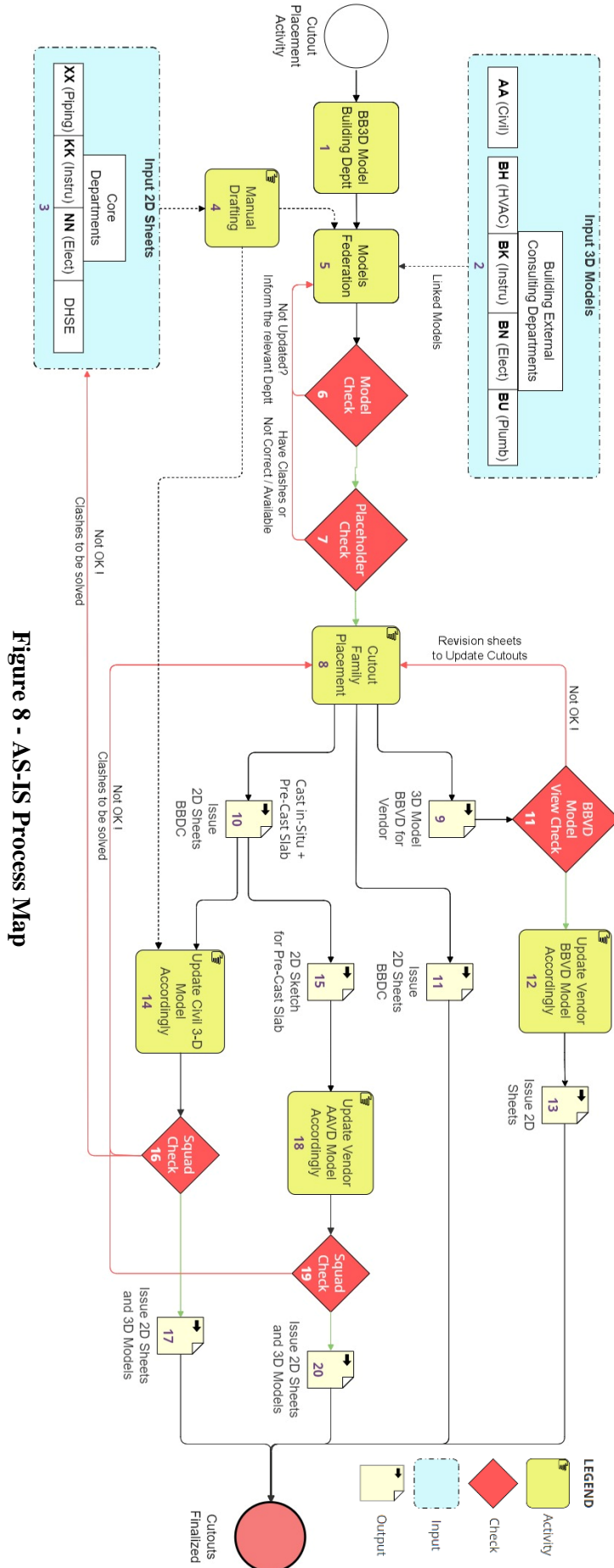


Figure 8 - AS-IS Process Map

4.2.2. TO-BE Process Map

The TO-BE process map depicts the cutout management process in its most effective form. To increase efficiency and effectiveness, it combines suggested changes, improved workflows, and streamlined tasks. This model offers a visual representation of the expected results, lays out specific goals, and directs how adjustments should be made.

Figure 9 on the following page, depicts the TO-BE BIM process map for the management of Cutouts activity. Each step in the workflow is indexed to represent the type of activity involved. Additionally, the activities are numbered to facilitate easy reference and detailed explanation in subsequent chapters.

The TO-BE BIM process map commences with the Architecture department creating the building model (activity 1) and receiving 3D Revit files from various external consulting departments, including HVAC, Automation and Control System, Electrical System, Instrumentation, Plumbing, and Civil departments (activity 2).

To enhance the BIM coordination process, the core departments, such as piping, instrumentation, electrical systems, and design health and safety environment, provide their inputs in 3D models (activity 3), eliminating the need for manual drafting.

A federated model is then prepared (activity 4) by integrating all the linked 3D models. This combined model undergoes a thorough 3D model quality control check (activity 5) and a check for placeholders, which indicate the location and type of cutouts (activity 6).

Next, openings are added using defined window families (activity 7). Once all the cutouts are placed, an intradepartmental clash detection and squad check take place (activity 8) to ensure proper positioning of cutouts and to resolve any potential clashes that may impact the cutouts.

The completed 3D model (activity 9) with all the cutouts is considered an output from the building department and serves as input for both the vendor and the civil department to update their 3D models accordingly (activity 12, 14). These updates integrate their respective inputs to finalize the cutouts activity.

Ultimately, the TO-BE BIM process workflow streamlines the coordination process by utilizing 3D inputs and performing comprehensive quality checks, resulting in improved accuracy and efficiency in managing cutouts. The 3D model acts as a valuable reference for stakeholders, ensuring smooth collaboration and the issuance of finalized 2D sheets and 3D models with the integrated cutout data.

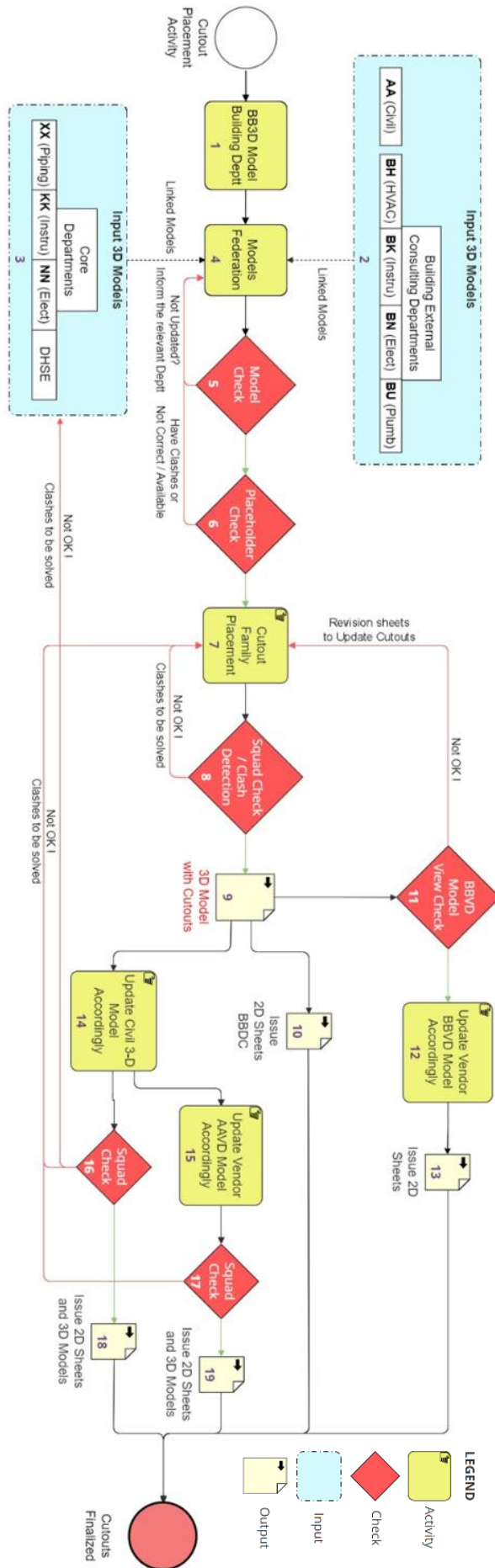


Figure 9 - TO-BE Process Map

4.2.3. Departmental Inputs

4.2.3.1. 3D Inputs

The BIM process for managing cutouts in a building project begins with the BB3D Revit model from the Building department, which serves as the foundation. To ensure comprehensive coordination and integration of various disciplines, other relevant Revit models (.rvt) are linked to the BB3D model. These models come from external consulting departments such as BH3D (HVAC), BJ3D (Automation and Control System), BN3D (Electrical System), BK3D (Instrumentation System), BU3D (Plumbing System), AA3D (Civil Concrete Department), and AI3D (Civil Steel Department). By combining these models, a federated model is created, incorporating all the essential elements that require openings in walls or slabs, such as HVAC ducts, cable trays, and pipes. Moreover, the model includes placeholders that precisely indicate the location and specific type of cutout required for each element. Figure 10 effectively showcases the different types of linked models to a BB3D model.

Manage Links

Revit	IFC	CAD Formats	DWF Markup
Link Name			
4300-AA3D-600280-BL464A.rvt			
4300-AAVD-3D-600280-BL464A.rvt			
4300-AI3D-600280-BL464A.rvt			
4300-BH3D-600280-BL464A.rvt			
4300-BJ3D-600280-BL464A.rvt			
4300-BN3D-600280-BL464A.rvt			
4300-BU3D-600280-BL464A.rvt			

Figure 10 - Example of Revit Linked Models to BB3D Model

4.2.3.2. 2D Inputs

In the AS-IS process model, the core departments, comprising Piping (XX), Electrical (NN), Instrumentation (XX), and the Design Health and Safety Environment (DHSE) department, used to provide input regarding cutout locations and types in 2D sheets with markups. Figure 11 illustrates a sample markup provided by the NN (Electrical Core Department). This type of input from multiple departments then also needs manual drafting and management to correctly identify the type of information provided and to inform the relevant department about it too. This approach was driven by two primary reasons.

- Typically, the core departments use software other than Revit for their modelling tasks, such as SP3D or Aveva software employed by the XX (Piping Department). Due to this software difference, direct integration of their models into Revit becomes challenging, leading to a lack of information about cutouts and their respective placeholders in the 3D models for elements designed by the core departments, potentially resulting in clashes with walls or slabs.
- Due to the involvement of multiple departments in the cutout management activity and the presence of colleagues accustomed to traditional drafting methods, it becomes challenging to persuade every department to adopt 3D digitalized input with metadata instead of submitting 2D sheets with markups.

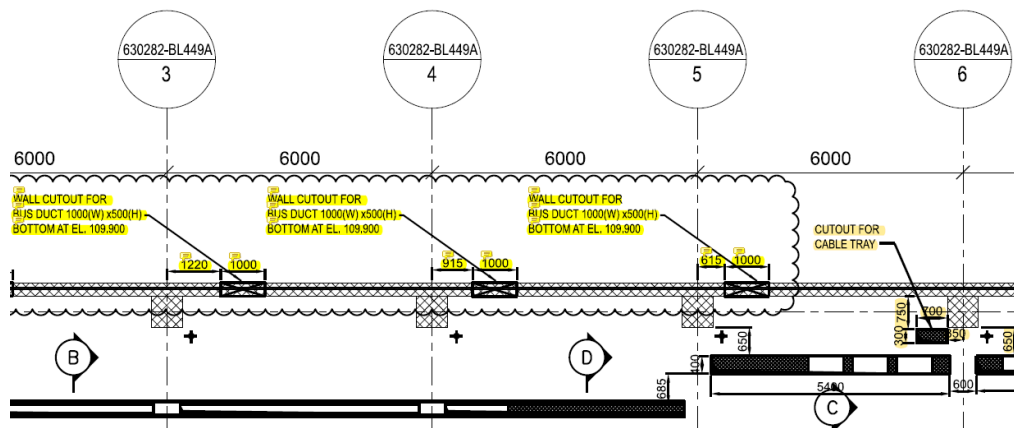


Figure 11 - Example of 2D Sheets with Markups

The proposed change in the TO-BE process model is to obtain inputs from Core Departments as 3D models, preferably in .ifc format, along with placeholder data. These 3D models will be integrated directly into the federated model, eliminating the need for manual drafting and coordination activities. This modification saves considerable work hours and ensures smooth management of cutouts, incorporating all departmental inputs seamlessly.

4.2.4. Placeholders

4.2.4.1. MagiCAD Placeholder Provisions

Placeholders are elements generated within Revit using the MagiCAD plug-in to serve as provisions for openings. Their purpose is to depict the necessary characteristics and dimensions of an opening needed at the point where a mechanical element intersects with a wall, floor, or ceiling element. The specific version of the MagiCAD plug-in utilized for openings management is illustrated in Figure 12.

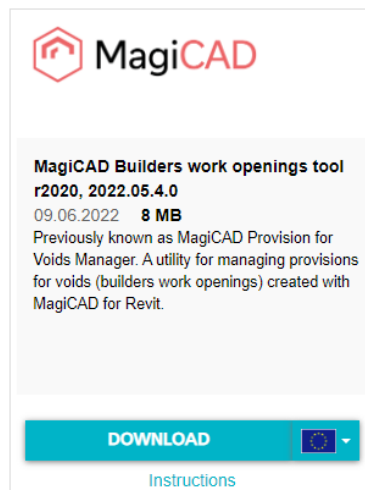


Figure 12 - MagiCAD Plug-in for Managing Openings

The utilization of these placeholder provisions offers the following advantages:

- Automatic identification of intersections between mechanical elements and their host components.
- Provision of a 3D-shaped element that precisely mirrors the required cutout shape at the intersection point.
- Automatic generation of voids or cutout families within host elements like walls, floors, and ceilings.
- Inclusion of relevant metadata within these placeholder provisions, crucial for selecting the appropriate cutout types and supplying metadata for individual cutouts.
- Enhanced collaboration between mechanical discipline modelers, primarily responsible for creating these placeholder provisions, and other discipline modelers. This collaboration is facilitated through reports generated using this plug-in.

Figure 13 depicts the interface of the MagiCAD plug-in, providing users with the capability to modify settings for provisions within the MagiCAD dataset.

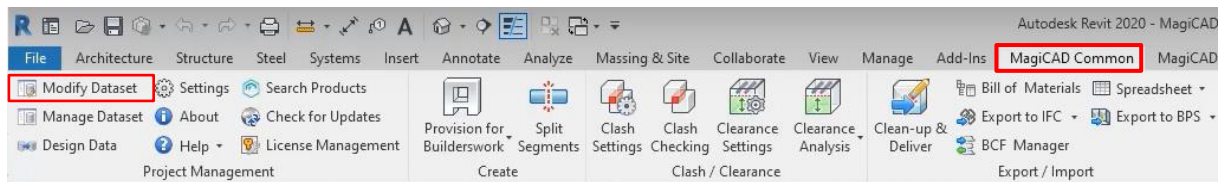


Figure 13 - UI of MagiCAD Plug-in on Revit

Figure 14 illustrates various options available for adjusting settings related to provisions for openings. Users can tailor discipline-specific offsets for the openings and include supplementary details like provision ownership, timestamps, and even a 2D symbol. A wide range of 2D symbol choices are available, depending upon factors such as provision angle, type, and the hosting element. Figure 15 shows the settings for the symbol of provisions.

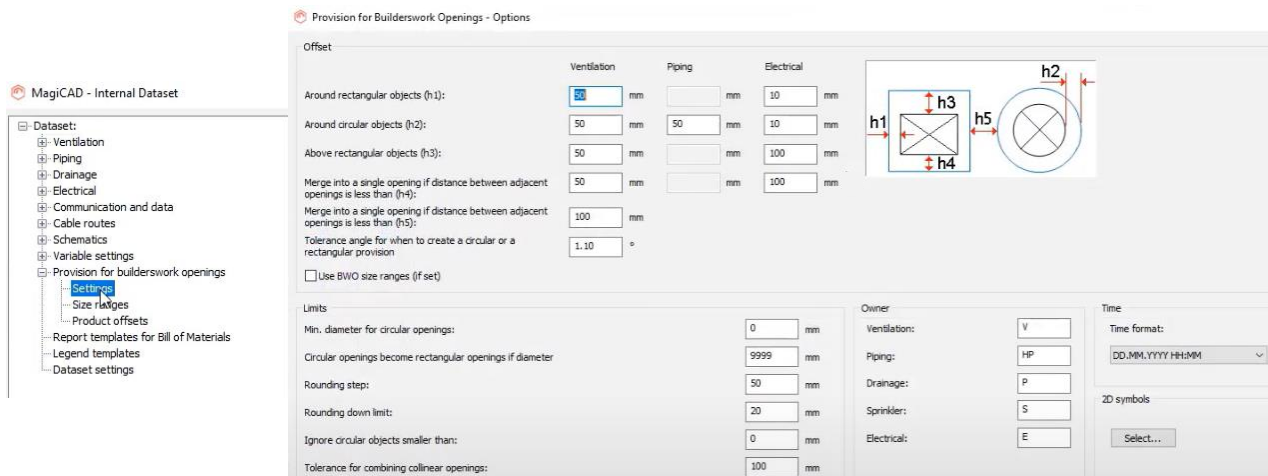


Figure 14 - Discipline Specific Settings for Provisions

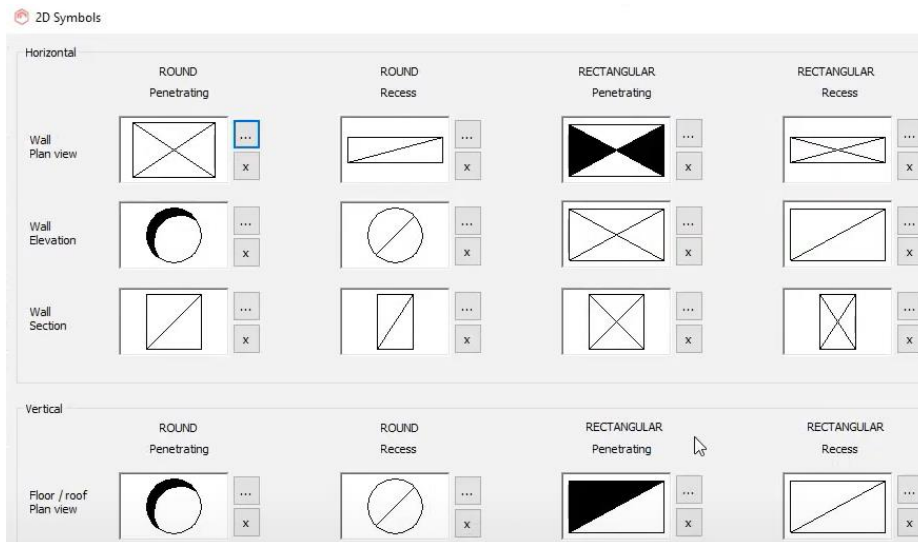


Figure 15 - Settings for the 2D Symbol of Provisions

Once the necessary settings for the provisions are configured, they can be generated automatically by choosing the appropriate mechanical equipment type along with the list of associated host elements. This process will initiate the creation of provisions within the model and generate a comprehensive list of the provisions that have been generated. The process of automatic provision creation is depicted in Figure 16.

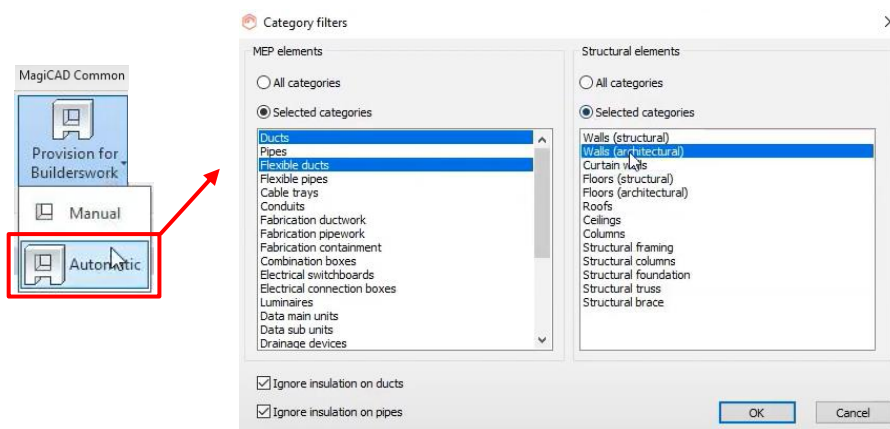


Figure 16 - Automatic Creation of Provisions

Once the placeholders are generated, any discipline modeler can link the file and subsequently generate voids automatically using the provided provision list. Each provision is assigned a unique ID and can be individually examined using the "show" option. Furthermore, the status of each provision can be marked as either accepted or rejected, accompanied by comments. This information can be compiled into a report that is then sent back to the provision owner for appropriate action. This approach facilitates smooth collaboration between the provision owner and other disciplines that utilize these provisions for incorporating cutouts into their modelled elements. Figure 17 offers a representation of a provision list as an illustrative example.

ID of Provision	Owner	Level	Status	Comments	Size	Host	Coordinates	ID of Void	Error or Warning
3064322	Vent	Level 1	Accepted		250	Wall	(8086, -3649, 128...	727483	
3064323	Vent	Level 1	Rejected		250	Wall	(6612, -3649, 128...	727481	
3064324	Vent	Level 1	Rejected		250	Wall	(3338, -3649, 128...	727479	
3064325	Vent	Level 1			250	Wall	(901, -3649, 12800)	727477	
3064326	Vent	Level 1			250	Wall	(-1601, -3649, 12...	727475	
3064327	Vent	Level 1			200	Wall	(561, -10839, 13...	727473	
3064329	Vent	Level 1			200	Wall	(1839, -10839, 13...	727471	
3064330	Vent	Level 1			200	Wall	(4239, -10839, 13...	727469	
3064331	Vent	Level 1			200	Wall	(6639, -10839, 13...	727467	
3064332	Vent	Level 1			200	Wall	(9039, -10839, 13...	727465	
3064333	Vent	Level 1			200	Wall	(11439, -10839, 1...	727463	
3064334	Vent	Level 1			200	Wall	(-39, -10839, 125...	727461	
3064335	Vent	Level 1			200	Wall	(2361, -10839, 12...	727459	
3064336	Vent	Level 1			200	Wall	(4761, -10839, 12...	727457	
3064337	Vent	Level 1			200	Wall	(7161, -10839, 12...	727455	
3064338	Vent	Level 1			200	Wall	(9561, -10839, 12...	727452	
3064339	Vent	Level 1			200	Wall	(13101, -7984, 13...	727449	
3064341	Vent	Level 1			200	Ceiling	(11733, -7984, 12...	727445	
3064343	Vent	Level 1			350	Floor	(10405, -5801, 52...	727441	
3064345	Vent	Level 1			200	Wall	(10661, -7984, 10...	727431	
3064347	Vent	Level 1			350	Wall	(10405, -5449, 12...	727423	
3064349	Vent	Level 1			500x500	Wall	(8777, -5449, 128...	727412	
3064351	Vent	Level 1			200	Wall	(11249, -5399, 12...	727408	

Figure 17 - Example of Provision List Generated

4.2.4.2. Placeholders Metadata Check

After obtaining the combined model, a thorough and random check happens within the main building model. This is done to make sure the placeholders are there and correctly placed in the linked models, especially for ducts, trays, and pipes where they intersect with walls and floors. This careful check ensures that everything lines up well and fits together smoothly, which is important for the project to work accurately.

Moreover, a comprehensive assessment of the metadata associated with these placeholder provisions is carried out. This guarantees accurate alignment of essential information. In Figure 18, multiple family types for these placeholders are presented. The choice depends on the specific mechanical equipment interacting with walls or floors. Two frequently utilized options include Void Provisions Rectangular Horizontal and Vertical. The selection is based on whether these placeholders are positioned within walls or floors.

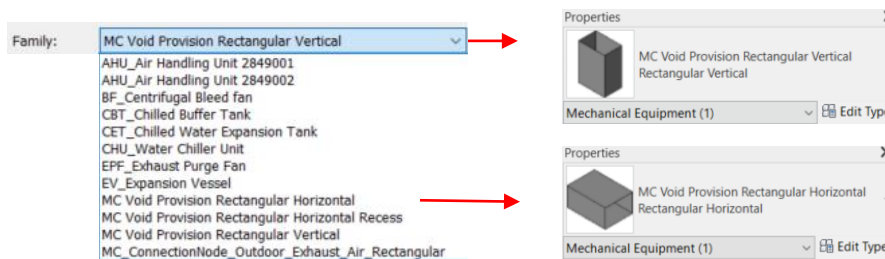


Figure 18 - List of Types of Families used for Providing Placeholders

Figure 19 illustrates essential metadata, encompassing the object code and sequence number for unique placeholder identification. The main item tag designates the relevant structure. The construction work area (CWA) label broadly represents the work area where the cutout should be located. The status property informs whether the related cutout is fixed, adjustable, or requires on-site drilling. Currently, the status property is not included in the present workflow. However, it is a suggested inclusion in the

proposed TO-BE process model. The cutout type property indicates its departmental relevance. Furthermore, the dimensions provided are subsequently utilized to place cutouts on the top of these placeholder provisions.

Data	
LV01_Object Code	BL
LV01_Sequence Number	449
LV01_Material Work Group	A
Main Item Tag	630282-BL449A
Equipment Tag	
CWA	630282
Status	Fixed or On Hold or Drilled on site
Cutout Type	BH
Dimensions	
MC Element Additional Length	40.0
Length_Tp	800.0
Width_Tp	600.0
Height_Tp	400.0

Suggested

Figure 19 - Required Metadata for Placeholders Provisions

4.2.5. Coutout Placement Activity

After confirming the adequacy of placeholder provisions within the federated model, the subsequent phase involves placing the cutouts within the architectural and civil models, depending upon where and which part of the building require those openings. These cutouts are outlined within the model using a dedicated custom window family, designed for the creation of these voids.

A total of six varied cutout families are outlined. These families design depends on the specific cutout shape, which could either be rectangular or round, corresponding to either pipes or ducts/trays. Additionally, the family design is influenced by the host element, which could either be a wall, floor, or roof element. Figure 20 illustrates the diverse cutout families defined, presenting their naming conventions as well as the distinct types linked to each family. These types are utilized to categorize the cutouts based on the various departments they relate to.

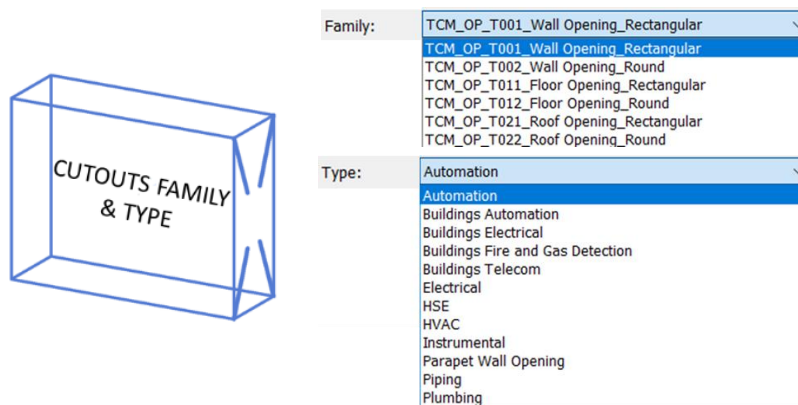


Figure 20 - Cutouts Family and its Types

Figure 21 is an example of an HVAC type rectangular cutout provided in a wall for a duct to pass through it.

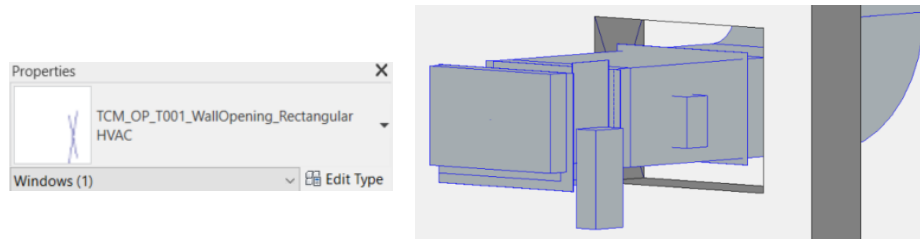


Figure 21 - Example of a HVAC Cutout for a Duct in a Wall

Figure 22 shows the metadata linked to these cutout window families. Height and Width are used to define the dimensions of the openings. Within the identity information, the Description outlines the provided cutout's type, while the Type Mark designates a distinct number for each cutout, providing individualized identity. This Type Mark can subsequently be utilized to portray each cutout on 2D sheets, facilitated by an item list table. The Cutout Type has the abbreviation value to signify the specific department it corresponds to.

Parameter	Value
Dimensions	
Height	1500.0
Width	1000.0
Identity Data	
Description	HVAC Wall Cutout
Type Mark	29
Other	
Cutout Type	H

Figure 22 - Parameters Associated with Cutout Family

Typically, the building department assumes the responsibility of manually placing the cutout window family at the exact position indicated by the placeholders sourced from linked models. The dimensions of these openings are derived from the metadata associated with the placeholders. As previously mentioned, the method of input for the cutouts can be either in the form of placeholder provisions (3D input) or manifested as markups on 2D sheets, depending upon the originating department. Figure 23 presents a sample architectural model of a building featuring incorporated cutouts.

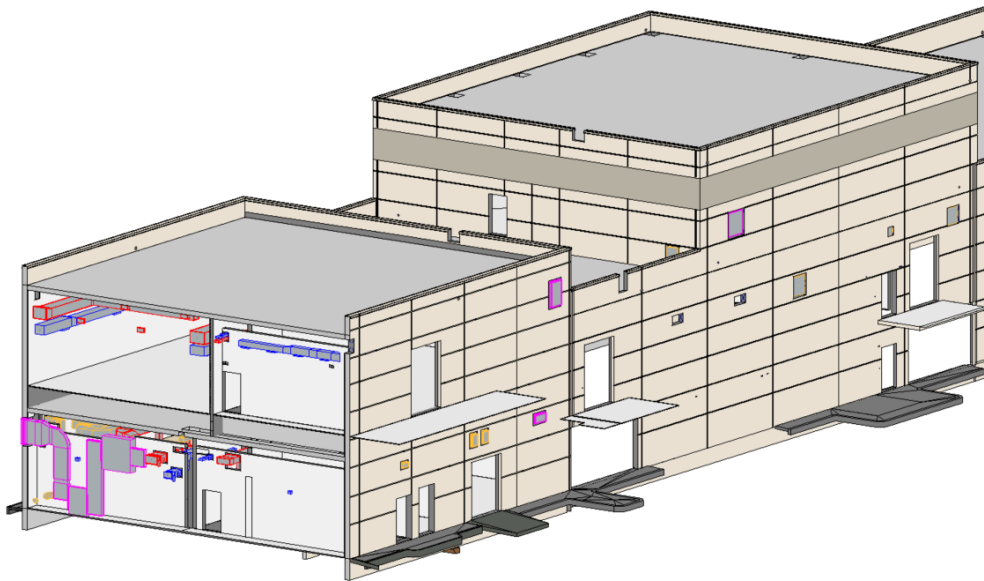


Figure 23 – 3D View of an Architectural Model with Cutouts

4.2.6. Intradepartmental Coordination and Clash Detection

BIM 360 serves as a common data environment, playing a vital role in managing documents and promoting coordination not only within the building department but also external departments, and core departments. This framework facilitates efficient document control and collaboration by bringing together various stakeholders.

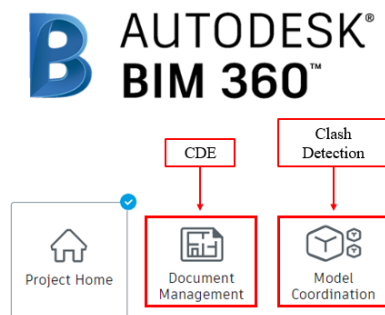


Figure 24 - BIM360 Platform as CDE and Clash Detection

Once all the cutouts are in place within a building, a significant step comes into play that is the squad check through the BIM360 Model Coordination platform. This check serves a crucial purpose which is to thoroughly examine possible clashes between key elements like ducts, trays, or piping and architectural model elements such as walls or floors. The squad check ensures cutouts are provided at exact location with the exact dimensions as per placeholder provisions inputs from linked models.

In essence, the squad check process revolves around aligning the latest versions of linked files with the architectural model's designated cutouts. This requires verifying that modified tray and duct routing configurations perfectly line up with the designated cuts. The accuracy of the building's overall architectural composition is maintained through the BIM360 Model Coordination platform. If there is a

clash and the cutout is either absent or not properly aligned with the routing, the clash is flagged as an issue to the concerned departments in BIM360.

4.2.6.1. Clash Detection with BIM360

The various views provided in the model in Revit for a particular building are used for model coordination in BIM360. Each model creates specific views that segment the building into smaller elements that are then easily added to a clash matrix to resolve the necessary clashes. Figure 25 displays the various types of views produced in various models. The recommended naming convention is “CD_(Specific Element)” where CD stands for clash detection.

These views are essentially organized based on the linked departmental models, further breaking down the segments to gather specific elements within a single view. This segmentation simplifies the clash detection process. Figure 26 illustrates the clash detection matrix within the BIM360 model coordination feature. This matrix employs the available views to cross-reference with one another, identifying potential clashes.

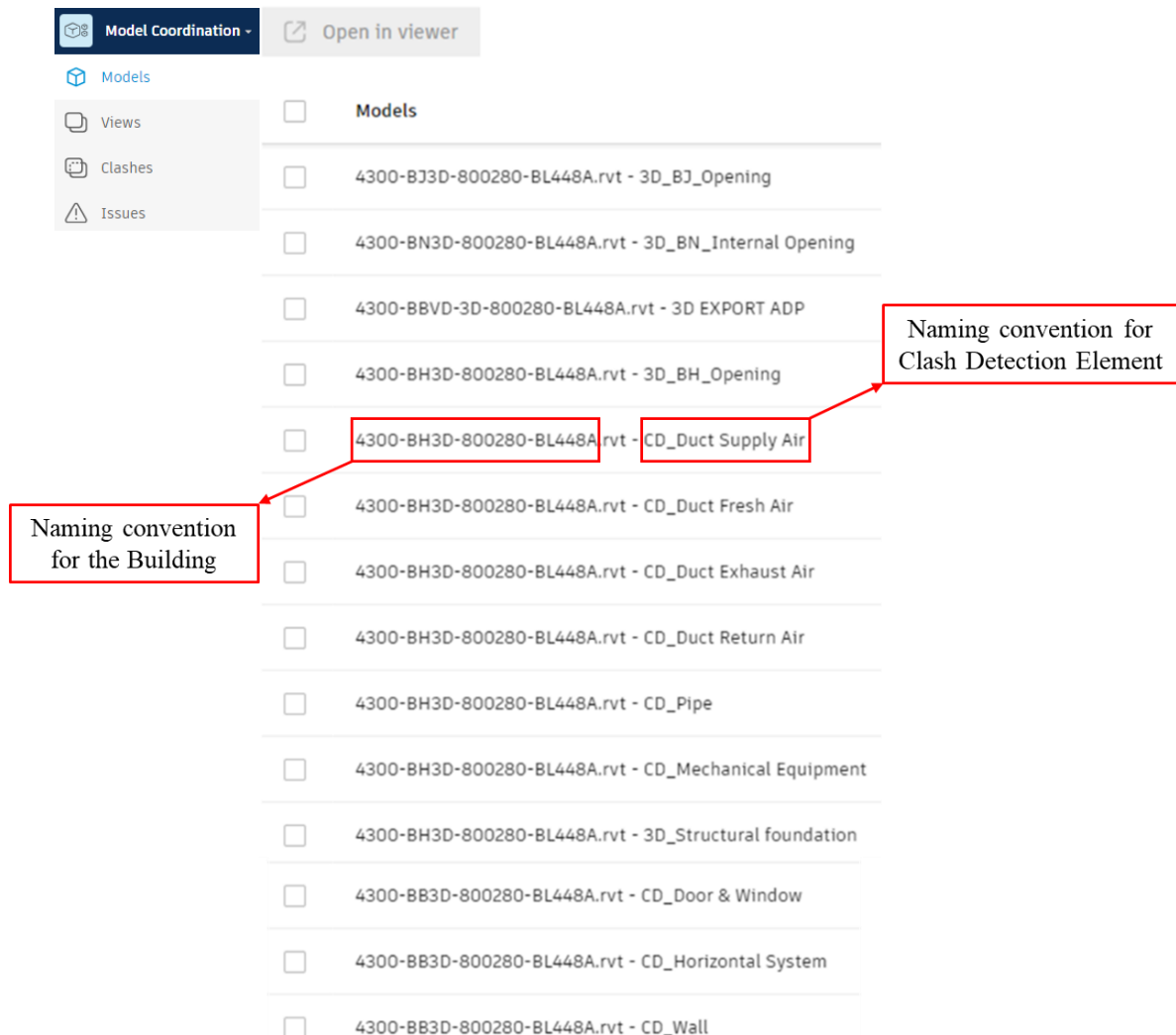


Figure 25 - Views with Naming Convention for Model Coordination

	4300-BB3...rvt - CD_... Ceiling	4300-BB3...rvt - CD_... Component	4300-BB3...rvt - CD_... Door	4300-BB3...rvt - CD_... Floor	4300-BB3...rvt - CD_... Roof	4300-BB3...rvt - CD_... Wall	4300-BB3...rvt - CD_... Window	4300-BB...re Rating	4300-BH...70-BL415A	4300-BH3...rvt - CD_... Air Ducts Exhaust	4300-BH3...rvt - CD_... Air Ducts Fresh	4300-BH3...rvt - CD_... Air Ducts Return	4300-BH3...rvt - CD_... Air Ducts Supply
4300-BB3D-133070...t - CD_Component 144 clash groups	25		3	77	32	46	2		1				
4300-BB3D-133070-BL415A.rvt - CD_Door 36 clash groups	2	4		4	2	14	2						
4300-BB3D-133070-BL415A.rvt - CD_Floor 88 clash groups		13	3		5	32			5	6	6	6	8
4300-BB3D-133070-BL415A.rvt - CD_Roof 27 clash groups		13	1	3		12			6	5	5	5	5
4300-BB3D-133070-BL415A.rvt - CD_Wall 399 clash groups	74	91	73	99	122		63		44	46	39	42	48
4300-BB3D-133070-BL415A.rvt - CD_Window 11 clash groups		2	1			3							
4300-BB3D-133070...vt - Fire Rating													
4300-BH3D-133070...3D-133070-BL415A 1189 clash groups	176	1		12	41	167				322	299	301	402
4300-BH3D-133070...Air Ducts Exhaust 715 clash groups	150			6	22	84			325		98	122	167
4300-BH3D-133070...D_Air Ducts Fresh 626 clash groups	150			6	22	49			303	99		117	150
4300-BH3D-133070...Air Ducts Return 675 clash groups	152			6	24	53			315	111	99		170

Figure 26 - Clash Detection Matrix with Views on BIM360

By utilizing the clash detection matrix, we have the capability to create an issue within the BIM360 platform. Figure 27 offers an instance of such a clash, where two ducts intersect a wall without the requisite cutouts for passage. Consequently, a new issue is created, in which we provide information about the title for clear identification. Furthermore, it requires allocation to the relevant individual from the respective department, accompanied by details regarding the underlying cause and a concise description of the encountered clash issue. The assigned individual is responsible for reviewing and resolving the created issue.

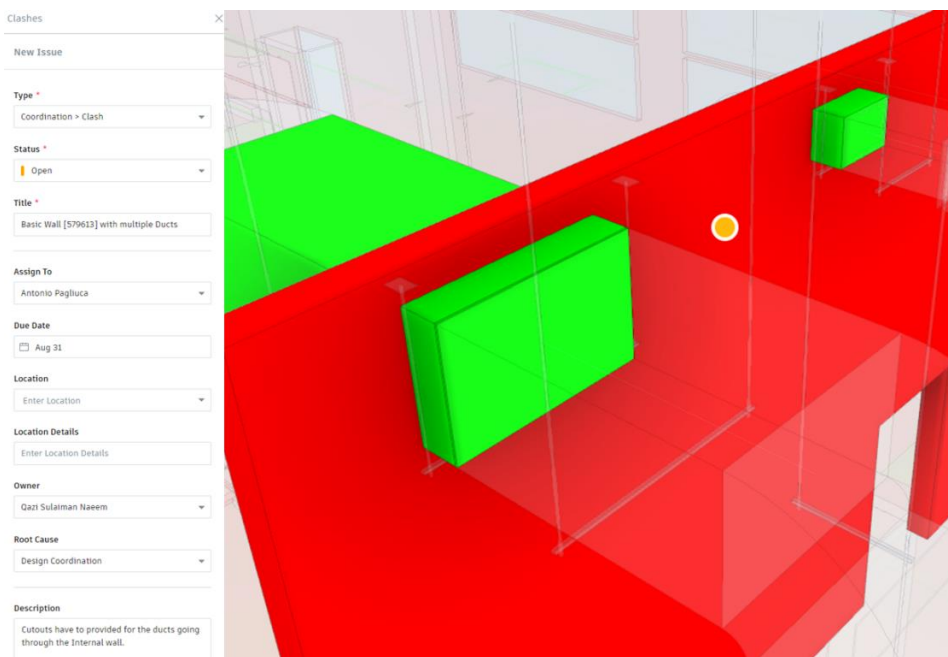


Figure 27 - Example of a Clash Assignment by Creating an Issue in BIM360

4.2.6.2. Pros of using BIM360 for Clash Detection

- Using BIM360 for clash detection offers a quick assessment of potential clashes in the model, without going into a detailed model check.
- Creating the clash detection matrix is a straightforward process, automated by BIM360 through the utilization of the various established views. Views that are not intended for clash detection matrix use can be designated as hidden, preventing their inclusion in the clash detection process.
- Clashes can be highlighted and linked to a screenshot, with automatic navigation to the specific clash site. This information is then directed to the appropriate individual in the relevant department using the already created database of CDE in BIM360.
- Since the clash detection matrix relies on views extracted from the uploaded .rvt files within the BIM360's document management section, which are routinely refreshed on a weekly basis, the clash detection matrix is likewise automatically updated. Consequently, new clashes are identified because of these updated models.

4.2.6.3. Cons of using BIM360 for Clash Detection

- Developing a comprehensive clash matrix presents challenges, particularly when trying to identify clashes for individual elements. This challenge arises due to clash matrix's reliance on entire views, making it unsuitable for detailed element-specific clash analysis.
- In contrast to the BCF Manager plugin for Revit, which permits automatic navigation to the clash within the Revit model for clash resolution, the same ease of navigation cannot be replicated using BIM360 model coordination. In the BIM360 environment, the navigation process occurs first, followed by the resolution of the clash within the Revit environment.
- Enforcing precise and detailed rules for clash detection, such as excluding particular element types from clash assessment or applying tolerance thresholds, is not achievable when utilizing Model Coordination in BIM360 for clash detection.
- Because of the inability to manually establish rules and tolerance levels, the clash matrix often flags numerous unnecessary clashes. These clashes must be navigated and resolved over time, a process that can be quite time-consuming and one can say, inaccurate too.

4.2.7. Outputs

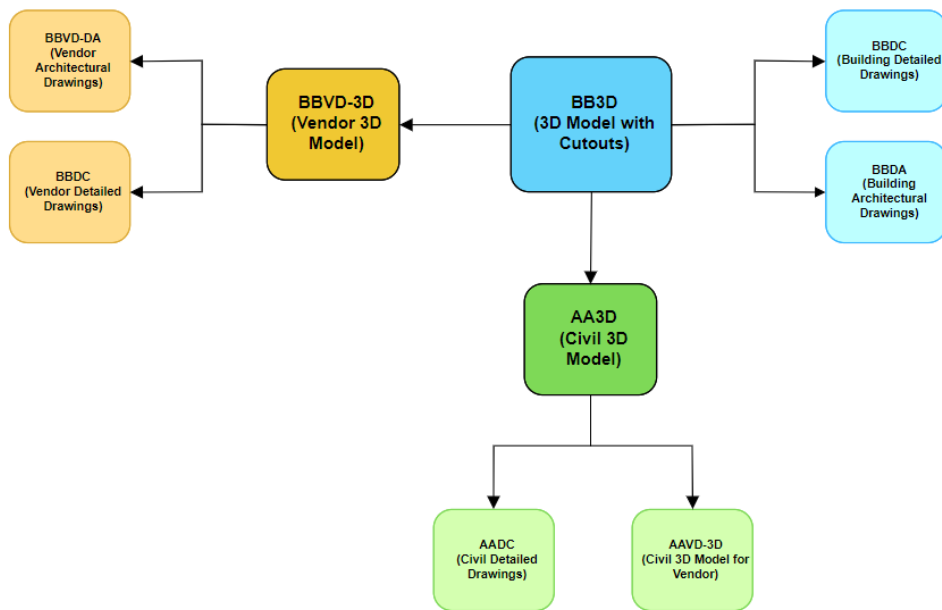


Figure 28 - Different Outputs from BB3D Model

Once the cutouts are strategically positioned and squad checks are finalized, the architectural model, now featuring the cutouts, is ready to provide multiple outputs for relevant departments. Figure 28 provides an overview of the output types originating from the 3D architectural model (BB3D). One output is the issuance of 2D drawings, including plans, elevations, and cross-sectional views for construction purposes, accompanied by material list tables connected to these drawings, known as BBDC (Building Detailed Drawings) output. Additionally, 2D general arrangement architectural drawings (BBDA) are produced, featuring typical details of the building's architectural views and a range of item libraries, such as doors, windows, floors, slabs, roofs, ceilings, and their connections. Moreover, the BBVD-3D (Vendor 3D Model) is updated using output from the BBVD view of the BB3D model. The AA3D (Civil 3D Model) also receives input from the BB3D model in the form of 2D sheets to ensure their model reflects the updates.

4.2.7.1. 2D Outputs from BB3D Model

The building department provides 2D results as BBDA (General Arrangement Architectural Drawings), including essential building dimensions, alignments, and placements. For items like walls, doors, windows, and floors, item tags are provided. These tags are then utilized to create elaborate schedules detailing wall finishes, window specifics, door particulars, and floor finishes. While the cutouts are present in the drawings, they lack detailed representation which is later done in BBDC drawings. Figure 29 shows an example of general arrangement drawing.

4.2.7.2. Outputs for BBVD-3D Model

In this particular case study, the vendor was accountable for producing the pre-cast panels for a segment of the building. Consequently, we needed to generate a dedicated 3D view from the building's BB3D model, specifically encompassing all precast panels along with their respective cutouts and related data. Figure 31 shows an example of a dedicated BBVD view within the BB3D model. The vendor would then utilize this view from our BB3D model as input for their own BBVD-3D (Vendor 3D model) and make necessary updates. In case of clashes or issues related to the cutouts provided to the vendor, revisions were carried out within the BB3D model to ensure the cutouts were updated accordingly.

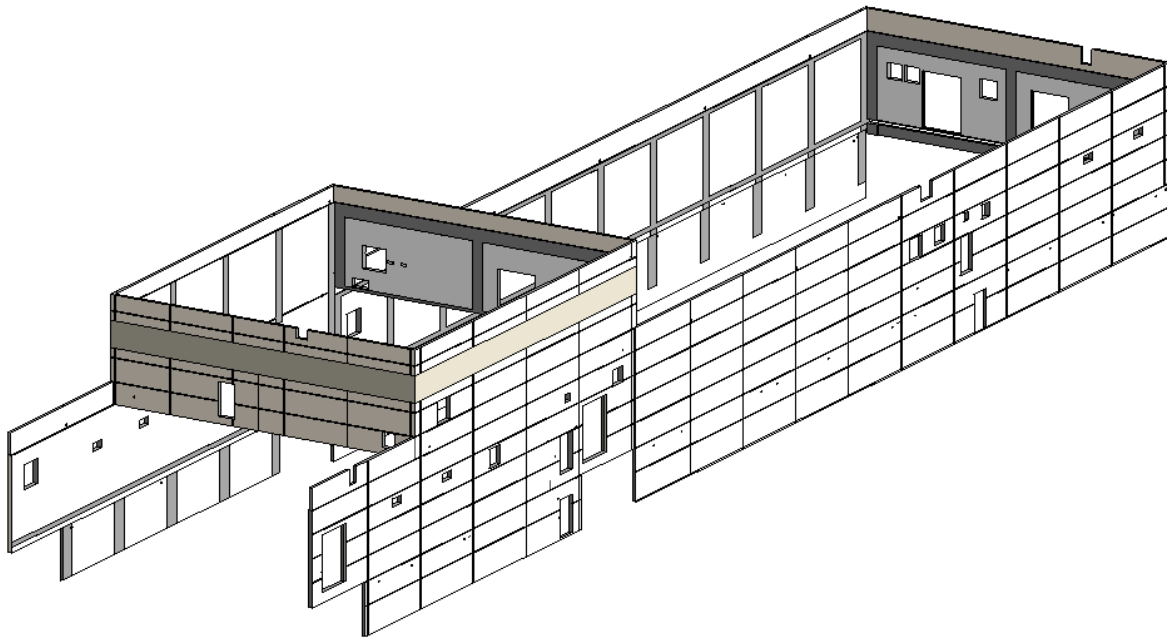


Figure 31 - Dedicated BBVD View in BB3D Model

4.2.7.3. Outputs for AA3D Model

In this particular case study, for the civil department according to the AS-IS process model, the output approach involves delivering 2D sheets intended for the cast-in-situ and precast slab sections of the building. These 2D sheets contain information about the cutouts within the cast-in-situ and precast slab components. The building department supplies this cutout data to the civil department. This input provision to the civil department is achieved through 2D sheets, driven by the civil department's specific requirement. Figure 32 provides an example of such input provided to the civil department, which then guides updates to the AA3D (Civil Department 3D Model) accordingly.

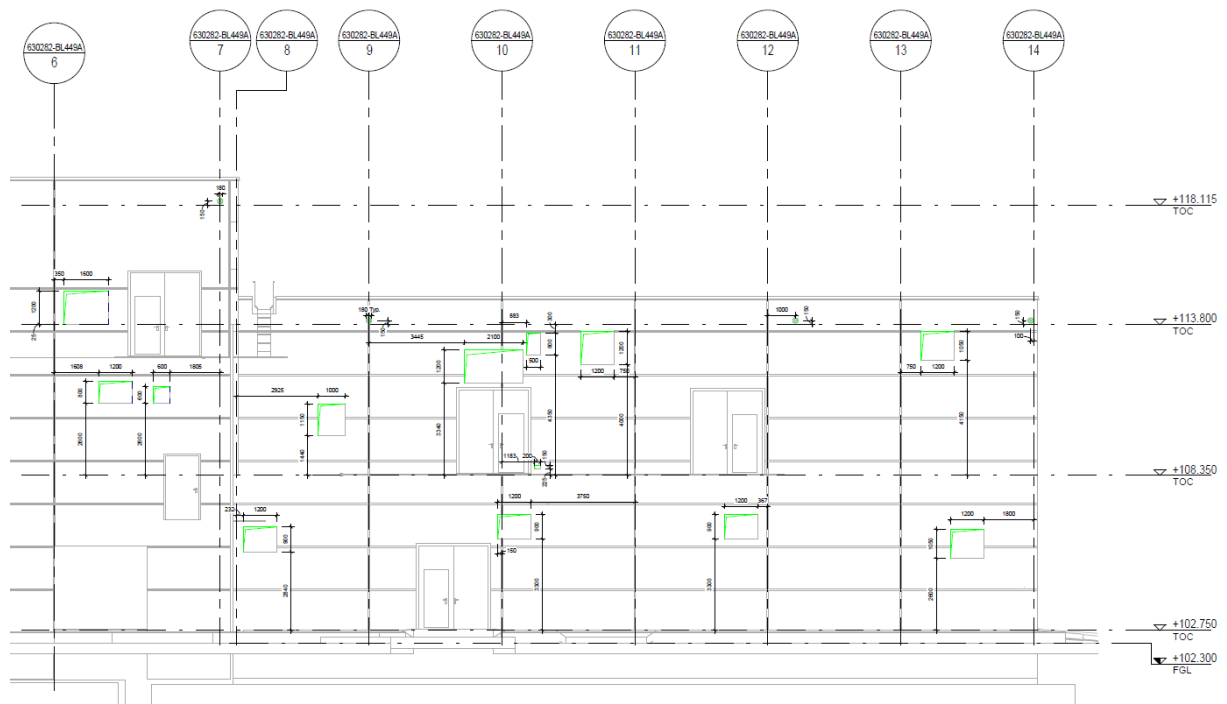


Figure 32 - Example of 2D Sheets as Input for Civil Department

One differentiating concept between the AS-IS and TO-BE models is the shift from providing civil department outputs in the form of 2D sheets to offering a distinct view within the BB3D model. This adjustment aims to furnish the civil department with comprehensive 3D outputs. However, this proposed alteration requires negotiation with the civil department, seeking their agreement to transition towards a 3D input approach from the building department model.

4.3. Interdepartmental Collaboration and Approval of the Proposed Workflow

The process for gaining approval for a proposed workflow within the organization entails extensive coordination with various departments. It involves a systematic approval procedure within each department, commencing with the creation of the workflow and initial approval from relevant personnel. Subsequently, a comprehensive discussion and presentation are conducted with the Engineering and Process Digitalization (EPD) department to introduce the proposed methodologies, which often incorporate the use of new software or plugins to achieve desired outcomes.

The EPD department must provide their approval for the proposed methodologies, which are then subject to further deliberation with the core departments participating in the workflow. Their approval is also sought. Finally, the process ends with the development of a work instruction document, accompanied by a final presentation of the proposed workflow to the head of plant design, who holds the authority to officially implement the workflow across the organization's departments. Figure 33 provides a visual overview of the step-by-step collaborative process involved in obtaining approval for the proposed workflow, with detailed explanations below.

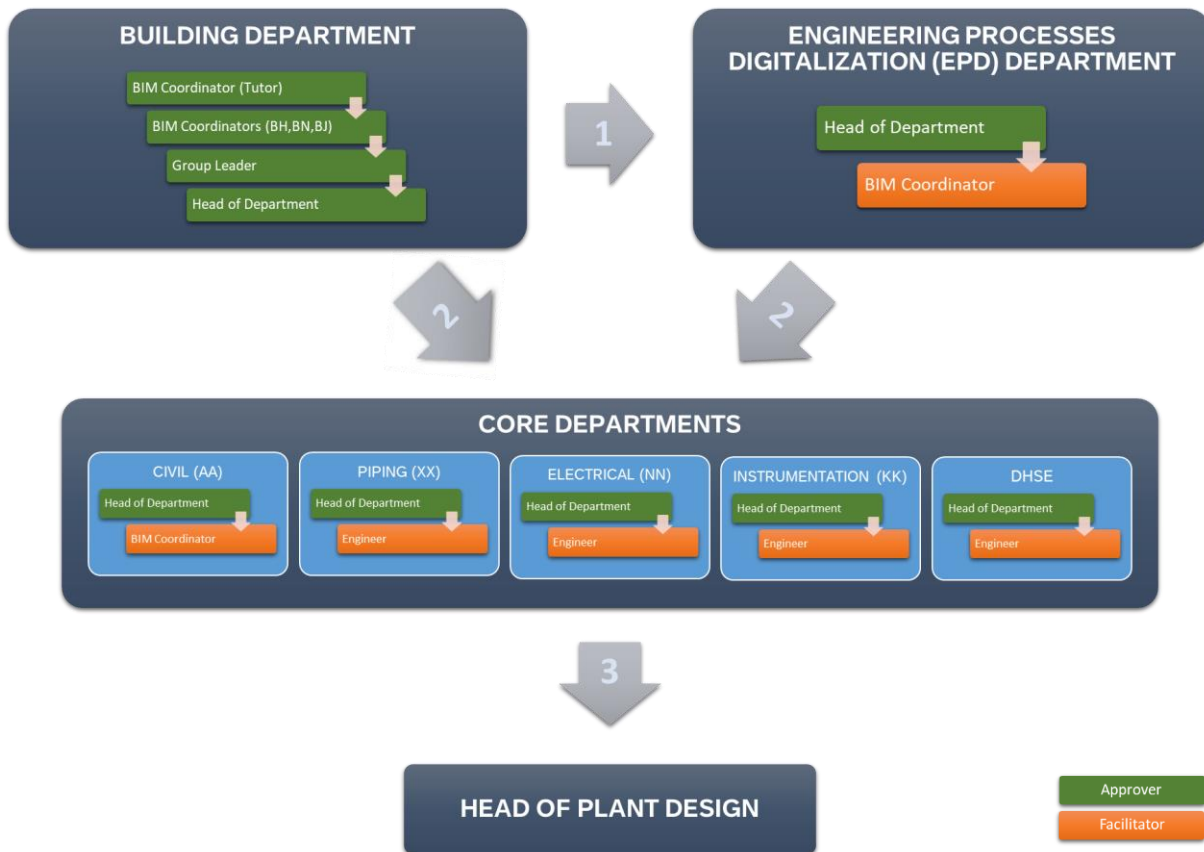


Figure 33 - Illustration of Interdepartmental Collaboration for the Proposed Workflow

4.3.1. Workflow Approval Within the Building Department

The initial phase involves crafting the proposed workflow, which is then practically examined with the BIM Coordinator from the building department. Once a well-structured workflow, representing the TO-BE process model, is developed, it must receive the BIM Coordinator's approval. Subsequently, a comprehensive presentation is given to other BIM Coordinators across various disciplines within the building department. Once consensus is reached among all BIM Coordinators regarding the proposed workflow, it proceeds to the department's group leader for review and suggested revisions, if any. The final step entails presenting the workflow to the Head of the Buildings Department, whose approval is the ultimate endorsement within the building department. This collaborative process unfolds systematically within the department, with the green blocks representing key approval points and the orange blocks signifying supporting roles in obtaining approvals as shown in the Figure 33.

4.3.2. Collaboration with EPD Department

The first step in our interdepartmental collaboration process involves consulting and presenting the proposed workflow to the Engineering Processes Digitalization (EPD) department. This consultation is crucial as it requires approval for the new methodologies proposed within the workflow, which may entail the adoption of new software and plugins to achieve desired outcomes. In our case study, this included seeking approval from the EPD department for the utilization of the MagiCAD plugin within Revit to manage Placeholder provisions. Additionally, the use of the MagiCAD plugin for Tekla,

specifically the Hole Reservation Manager plugin, aimed at automating the creation of cutouts in the IFC federated model, was also presented as an integral part of the workflow.

The primary objective is to introduce the proposed workflow and its associated methodologies to the Head of department of EPD. Subsequently, collaboration takes place with the EPD department's BIM Coordinator to collect valuable feedback and seek approval for the workflow.

4.3.3. Collaboration with Core Departments

The second step in the interdepartmental collaboration for workflow approval involves working closely with the core departments of the organization. After obtaining approval from the EPD department, representatives from both the Building and EPD departments jointly present the proposed workflow and the new methodologies required to achieve and effectively manage the cutouts. These presentations are made to the Head of departments of all the core departments participating in the workflow. The Heads of departments must either provide their approval or offer feedback for implementation within the workflow through consultation with their respective BIM Coordinators or Engineers. Approval from all department heads within the core departments is essential to finalize the proposed workflow. Figure 33 shows the relevant core departments involved in the proposed workflow for cutouts management.

4.3.4. Presentation to the Head of Plant Design

The third and concluding step in securing approval for the proposed workflow involves the development of a comprehensive work instruction document by the Building Department. This document is created after the consultations and approvals obtained from both the EPD and Core Departments. The work instruction document serves as a detailed guide, providing step-by-step instructions for the proposed workflow in managing cutouts.

This document carries official status within the organization and is accessible via the organization's database for any future activities related to cutout management. A concise presentation is then prepared and delivered to the Head of Plant Design, who holds authority over all departments engaged in industrial plant design projects. Final endorsement of the proposed TO-BE workflow is granted upon the approval of the Head of Plant Design.

4.4. Automatization of Cutout Placement Activity

As mentioned in previous chapters, the placement of window families in the architectural model to create cutouts on top of the provided placeholders is currently a manual activity. This process requires a significant amount of work hours and coordination among multiple individuals to ensure that the desired openings align with the input received from other departments through linked models. The manual nature of this task often leads to a time-consuming and labor-intensive process.

To address this issue, the objective is to explore ways to automate and improve the management of this process. One simple idea is to develop a Dynamo script that can automate the creation of the required openings based on the specific inputs provided. By programming this script to analyze the input parameters and generate the openings accordingly, it reduces the need for manual intervention and accelerates the overall workflow.

Furthermore, it is essential to consider the need for incorporating models from core departments that do not typically use Revit for modelling. In order to achieve a more comprehensive and efficient approach, the incorporation of these models can be facilitated through the use of the MagiCAD plug-in for Tekla. This not only provides a platform for integrating non-Revit models but also enables better management of the openings throughout the design and construction process.

By automating the process of creating openings and incorporating models from various departments, the aim is to streamline the coordination efforts and reduce the manual workload associated with managing building openings in the architectural model. This automation and improved management will help enhance efficiency, accuracy, and overall project coordination, ultimately leading to time and cost savings for the organization.

4.4.1. Dynamo Script

To automate the process of placing cutouts, a Dynamo script was created, as illustrated in Figure 34. This script specifically targeted the task of creating openings in the building architectural model (referred to as BB) for accommodating ducts that goes through walls and floors from the building HVAC linked model (referred to as BH).

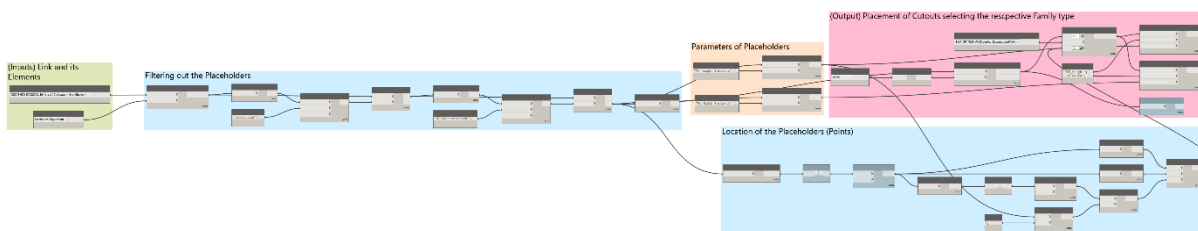


Figure 34 - Dynamo Script for Automatic Placement of Cutouts

4.4.1.1. Input Link and its Elements

As the cutouts are required for items sourced from linked models, it is necessary to obtain the linked model as an input, along with the associated placeholders provisions placed where the elements of linked model overlap with the walls or floor elements of the architectural model. The placeholders are identified as mechanical equipment, thus the category of placeholders in the script are taken as mechanical equipment. Figure 35 shows the input part of the script.

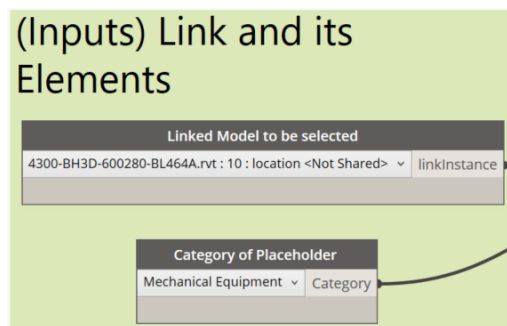


Figure 35 - Inputs for the Script

4.4.1.2. Filtering the Placeholder Provisions

This stage involves the extraction of placeholder provisions specifically from all mechanical equipment present in the model and the linked models. The underlying concept involves considering elements from the linked model and then applying a filtering process using the string "MC_ConnectionNode" to isolate and provide their respective geometries. Figure 36 illustrates the script devised for this task.

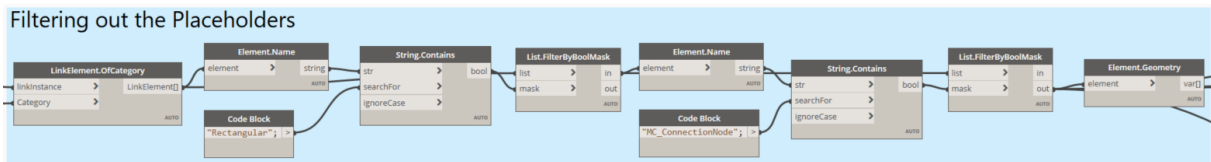


Figure 36 - Filtering Phase of the Placeholders

4.4.1.3. Parameters from the Placeholder Provisions

Once the filtering process successfully identifies the placeholders within all mechanical equipment, the subsequent phase involves retrieving essential metadata required for the corresponding cutouts to be positioned precisely over these placeholders. The crucial data we seek includes the dimensions of the cutouts, which can be obtained from the metadata of the placeholders. Specifically, we extract the "MC Height Instance" value to determine the height and the "MC Width Instance" value to acquire the width of the cutouts, which will be added later. Figure 37 shows the commands used to acquire this data.

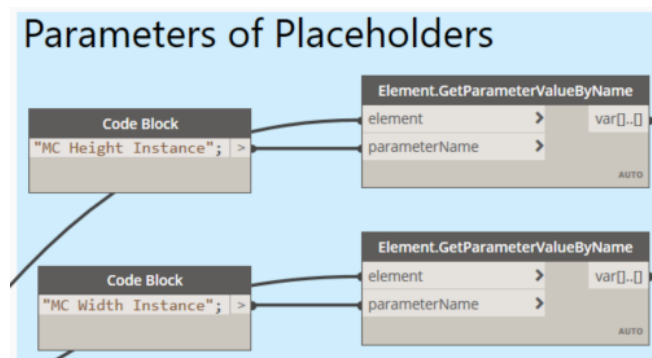


Figure 37 - Acquiring Parameters from Placeholders

4.4.1.4. Locating the Placeholder Provisions

To precisely position the cutouts precisely over the placeholders, we must initially obtain the location of these placeholders. To achieve this, we extract the location of each placeholder, separating the values for the x, y, and z axes into distinct lists for each placeholder. Given that the z-axis point denotes the top surface point, we then divide it by half of the height value of each placeholder. This division yields the midpoint along the z-axis, effectively providing us with the midpoint coordinates across all three axes. Figure 38 shows the script for locating the midpoint of these placeholders.

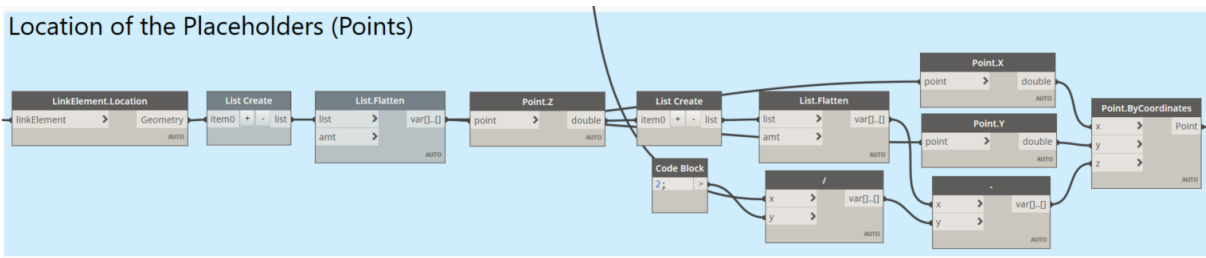


Figure 38 - Locating the Placeholders

4.4.1.5. Placement of the Cutouts Family

The final step involves positioning the cutouts precisely on top of the midpoints of the placeholders. To achieve this, we first need to specify the type of cutout family required, which can be chosen from the list of family types within the model. For the current scenario, dealing with the HVAC linked model, we can select the family type rectangular opening for HVAC. These cutouts are actually provided by inserting window families. To place these window families, we require a host element. In this case, we can use walls as the host elements. To identify the walls that will serve as host elements, we perform an intersection between the walls in the model and the list of placeholders. This process helps us identify the specific walls where the cutouts need to be precisely located.

Once we have the list of host elements and the coordinates for the cutouts, we can position the cutouts at the exact locations while using the dimensions obtained earlier from the metadata collected from the placeholders. Figure 39 illustrates the commands utilized in this part of the script to generate all the cutouts within the model.

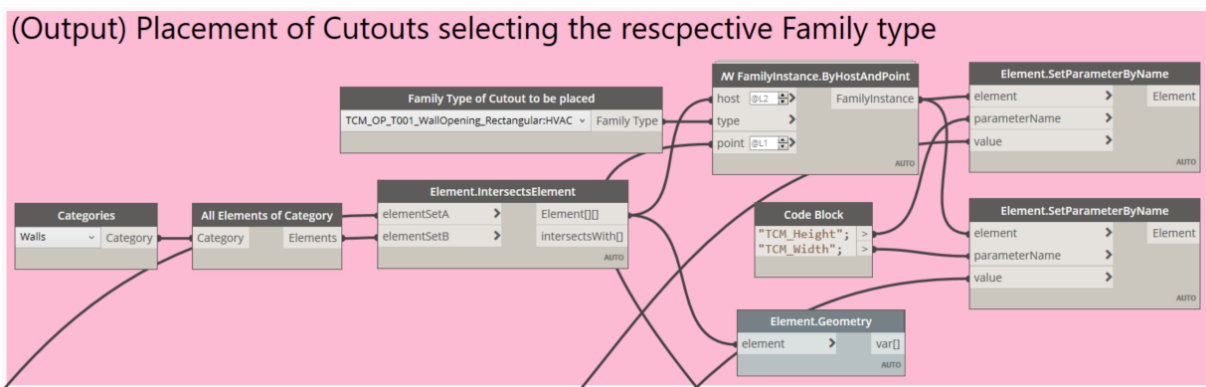


Figure 39 - Placement of the Cutouts

4.4.1.6. Interface of Script in Dynamo Player

To use the script directly from the Dynamo Player, certain inputs were defined. These inputs include selecting the linked model to filter out the placeholders from the link and specifying the category of the placeholder. Additionally, input was required to determine the type of family for the cutouts. Figure 40 displays the script's interface within the Dynamo Player.

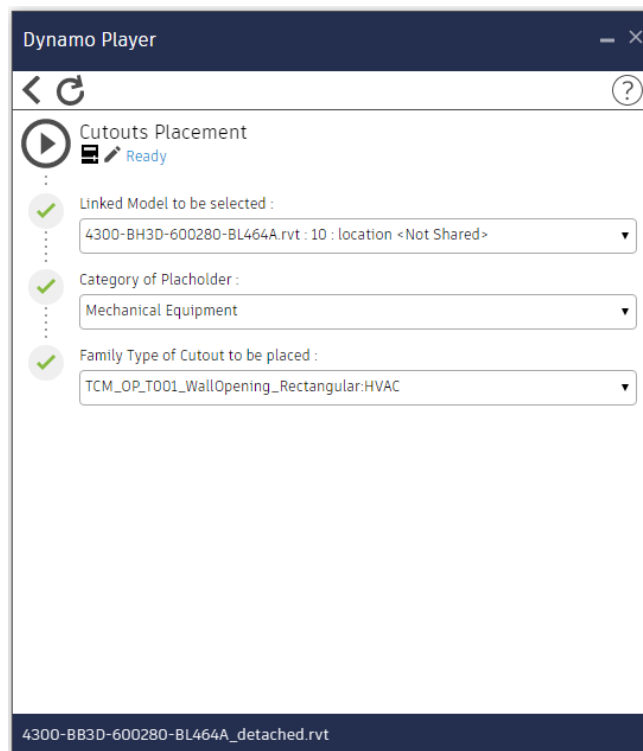


Figure 40 - Dynamo Player Interface for the Script

4.4.2. Tekla-MagiCAD Plugin

To acquire cutouts in models from departments not utilizing Revit, we can leverage Tekla software. By gathering ifc files from various departments and deploying the MagiCAD plugin within Tekla, we can efficiently generate and oversee the required openings. The relevant plugin, named "Hole Reservation Manager," is available in Tekla Warehouse, as illustrated in Figure 41 along with its description.



Figure 41 - MagiCAD Plugin in Tekla Warehouse

4.4.2.1. Creating Ifc file for Placeholders only

In addition to obtaining ifc format files for each department's models, we also require an ifc version of the placeholders created exclusively using the MagiCAD placeholder plugin in Revit. This specific ifc file serves as the foundation for conveying information about the cutouts to be generated in Tekla. Figure 42 displays the view comprising only placeholder provisions that need to be exported as an ifc file, encompassing all the metadata of these provisions.



Figure 42 - Example of only Placeholder Provisions View

4.4.2.2. Model Federation in Tekla

To establish a federated model in Tekla, it's necessary to have ifc versions of the models from all departments, along with the ifc file containing placeholder data. Once all the required ifc files are available, we can create a federated model in Tekla by utilizing the reference model feature, as illustrated in Figure 43.

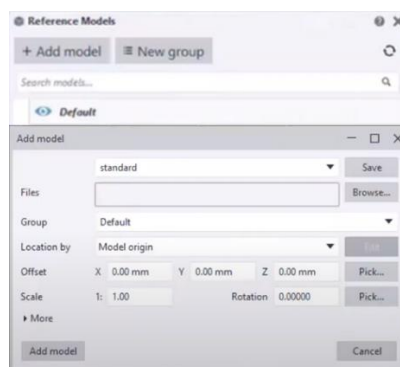


Figure 43 - Model Reference Feature in Tekla

4.4.2.3. Creating Openings using Hole Reservation Manager

Once all the models are uploaded as reference models to create the federated model in Tekla, we can initiate the Hole Reservation Manager plugin in Tekla. The initial step involves selecting the ifc model of placeholder provisions and choosing the "Get Model" option within the plugin's main dialogue box. This action retrieves information about all the placeholders from the attached Ifc file, as depicted in Figure 44.

System	Note	Shape	Status	Comment	BottomLevel	Size	Tolerance	Assigned to	Hole
S		Rectangular	New		113865	500*200	0		
S		Rectangular	New		113865	500*200	0		
S		Rectangular	New		113865	500*200	0		
S		Rectangular	New		113865	500*200	0		
S		Rectangular	New		113865	500*200	0		
S		Rectangular	New		113865	500*200	0		
S		Rectangular	New		113865	500*200	0		
S		Rectangular	New		113325	500*150	0		
S		Rectangular	New		113325	500*150	0		
S		Rectangular	New		113865	500*200	0		
S		Rectangular	New		113865	500*200	0		
S		Rectangular	New		113865	500*200	0		
S		Rectangular	New		113865	700*200	0		
S		Rectangular	New		113865	700*200	0		
S		Rectangular	New		113325	500*150	0		
S		Rectangular	New		113865	500*200	0		

Figure 44 - Acquiring the Placeholder Provisions Information

After the application collects information about the placeholder provisions, one can modify the status of each placeholder from "New" to "Accepted as requested = 1," as indicated in Figure 45. By selecting the "Update" button on the right of the dialogue box, a hole reservation component is generated within the Tekla model for each placeholder, illustrated by the red box in Figure 46. Finally, the "Hole" button is employed to produce an actual cut or opening in the Tekla federated model, as shown in the final step of Figure 46.

System	Note	Shape	Status	Comment	BottomLevel	Size	Tolerance	Assigned to	Hole
PU		Rectangular	Accepted as requested = 1		113915	300*150	0		
PU		Rectangular	Accepted as requested = 1		113915	300*150	0		
PU		Rectangular	Accepted as requested = 1		113915	300*150	0		
PU		Rectangular	Accepted as requested = 1		113915	300*150	0		
PU		Rectangular	Accepted as requested = 1		113915	300*150	0		
PU		Rectangular	Accepted as requested = 1		113915	300*150	0		
PU		Rectangular	Accepted as requested = 1		113915	300*150	0		
PU		Rectangular	Accepted as requested = 1		113915	300*150	0		
PU		Rectangular	Accepted as requested = 1		113915	300*150	0		
PU		Rectangular	Accepted as requested = 1		113915	200*150	0		
PU		Rectangular	Accepted as requested = 1		113915	300*150	0		
PU		Rectangular	Accepted as requested = 1		113915	300*150	0		
IV		Rectangular	Accepted as requested = 1		113915	520*160	0		
IV		Rectangular	Accepted as requested = 1		113915	500*600	0		
IV		Circular	Accepted as requested = 1		112645	210	0		

Figure 45 - Status Update to Create Openings

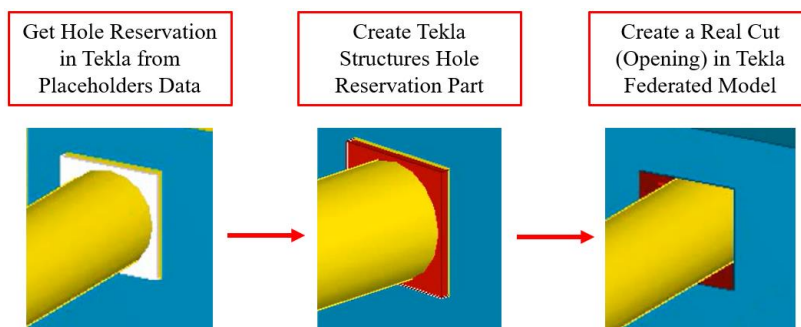


Figure 46 - Visual Steps to get an Opening in Tekla Federated Model

When there are updates to the placeholder location, size, removal, or new placeholders are added, it is essential to ensure that these updates are carried out using the MagiCAD placeholder plugin in Revit. This is to ensure that the GUID of the placeholder remains unchanged. Once these updates are made, an updated version of the ifc file containing the placeholder provisions can be uploaded to Tekla.

In Tekla, by attaching this updated ifc file of placeholder provisions in the Hole Reservation Manager plugin, one can easily filter out the revised placeholder provisions by checking the "Revised" option.

The status of these updated placeholders can then be changed from "Revised" to "Accepted as requested = 1," as demonstrated in Figure 47. By clicking the "Update" button to the right of the dialogue box, all previously created hole reservations will be updated according to the new information contained in the file and updated openings can then be created eventually.

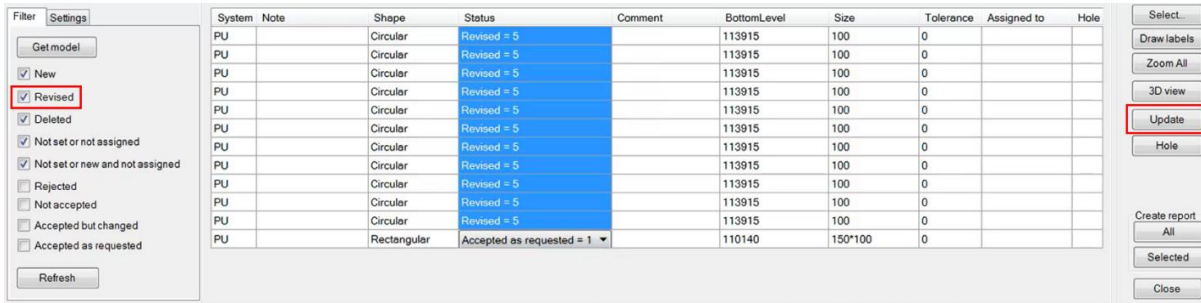


Figure 47 - Managing the Updated Placeholder Provisions

5. CONCLUSION

Efficiently managing MEP design, particularly in industrial plant projects, is crucial. Collaboration among departments plays a pivotal role in this, aided by BIM. This study aimed to propose an improved workflow for cutout management within the industrial plant project. In industrial plant projects, efficient cutout management is crucial. This study began by examining the current AS-IS process model, which was labour-intensive. This initial phase revealed shortcomings and served as the basis for the detailed TO-BE process model presented in this study. The transition from the existing AS-IS process model to the envisioned TO-BE process model is a key focus of the study, highlighting its importance. The examination of the TO-BE process model has revealed several crucial areas that were addressed:

Transitioning to 3D: Recognizing the growing need for 3D representations, the study explored ways to acquire 3D inputs. This was achieved by employing MagiCAD Placeholder Provisions, a tool that automated the process of collecting data and representing the openings in 3D, where needed. Furthermore, the transition from producing 2D sheet outputs to generating 3D model views to exchange information regarding cutouts, not only saved a significant amount of time but also streamlined the workflow effectively. Importantly, it signified a departure from traditional information exchange practices and enhanced collaboration across departments.

Automatization: To reduce manual effort, save considerable work hours, and minimize the risk of human error, several activities were automated. This included creating placeholder provisions to identify openings, placing cutout families on these placeholders using Dynamo scripts, and utilizing the Hole Reservation Manager in Tekla to generate openings in the federated model, which included models from departments not using Revit for modelling.

Collaboration and Clash detection: The departments worked together closely, utilizing BIM360's model coordination feature to detect and address potential issues and clashes between the mechanical equipment and the respective cutouts provided in the architectural models. Any identified issues were assigned to the relevant personnel for resolution. While using model coordination feature of BIM360 for clash detection purposes had its drawbacks especially in terms of providing manual rules to identify the require clashes only, it still proved highly beneficial for managing clash detection related to cutouts.

Workflow Created, Approved and Documented: The TO-BE process model underwent an internal approval process within the building department before receiving approval through collaboration with other relevant departments. Subsequently, it was documented as an official work instruction document for the organization to guide future cutout management activities.

Although the updated workflow has proven valuable for the organization, there remains room for future enhancements. This includes exploring new collaboration methods with departments that use software other than traditional BIM tools like Revit or Tekla, such as SP3D for piping. These variations can pose challenges in obtaining 3D input data for cutouts. Additionally, there is potential to refine the efficiency of Dynamo scripts, making them more user-friendly, and implementing checks to maintain workflow integrity. This signifies ongoing efforts to further optimize and streamline our processes.

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LIST OF ACRONYMS AND ABBREVIATIONS

They are to be listed transparently, logically separated, in column (tabular) form. Acronyms / abbreviations / translations that are not in the public domain should be indicated. Acronyms / abbreviations / translations in the list are to be listed in alphabetical order. Acronyms and abbreviations are to be indicated in the List of Acronyms and Abbreviations.

Example:

BIM	Building Information Modelling
AEC	Architecture, Engineering, and Construction
AA	Civil Department
AAVD	Civil Department Vendor Model
ARC	Architectural
E&I	Electrical and Instrumentation
M&P	Mechanical and Plumbing
CWA	Construction Work Area
EPD	Engineering and Process Digitalization Department
BB3D	Building Department 3D BIM Model
BBVD	Building Department Vendor Model
BBDA	Building Department General Arrangement Drawings
BBDC	Building Department Detail Drawings
BBDT	Building Department Typical Drawings
BB	Building Department
BH	Heating, Ventilation, Air Conditioning
BJ	Building Automation & Control System
BK	Fire and Gas System
BN	Building Electrical Systems
BT	Telecom System
BU	Building Plumbing Systems
DHSE	Health and Safety Department
KK	Plumbing Department
NN	Electrical Department
XX	Piping Department
...	...