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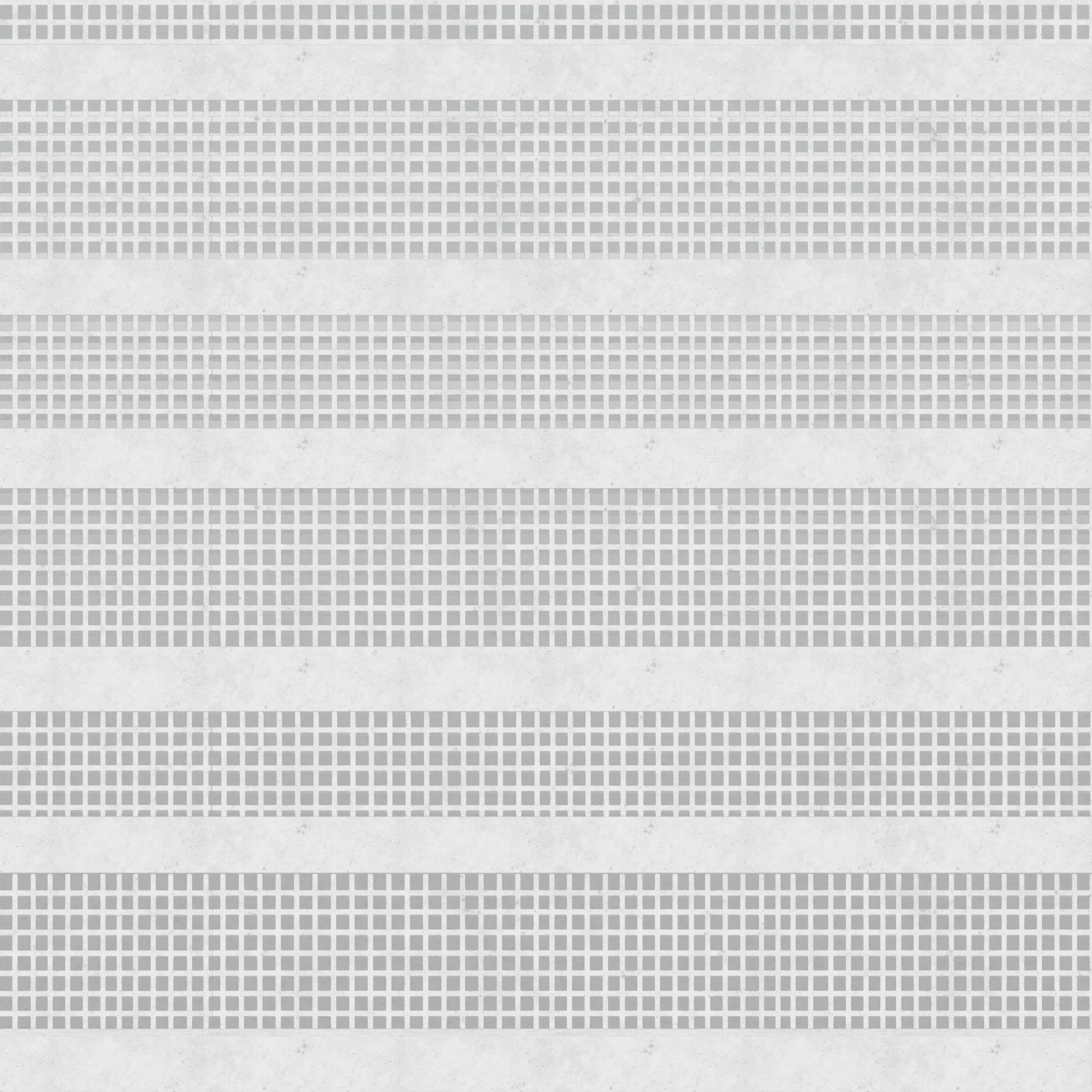
BIM-BASED METHODOLOGY



GUIDELINES FOR RETROFIT PROJECTS: BIM-BASED METHODOLOGY

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FOREWORD

The application of Building Information Modeling (BIM) as a methodology for developing integrated building design projects has increased significantly over the past decade. Although BIM enables rapid and accurate responses to the demands of the real estate and construction sectors, it still requires adjustments to support certain functions, particularly those related to site-specific interventions and projects involving existing buildings (retrofit). Within this context, the present document aims to present the technical procedures for developing a retrofit project using BIM.

The content of this manual is the outcome of a research project funded through Public Call 04/2021 by the Research Support Foundation of the Federal District (FAPDF). The initiative involved a multidisciplinary team composed of four faculty members, twelve undergraduate students, and three technical staff members from three federal higher education institutions: the Faculty of Architecture and Urbanism and the Faculty of Technology, both from the University of Brasília (FAU-UnB and FT-UnB); the Faculty of Architecture, Engineering, and Technology at the Federal University of Mato Grosso (FAET-UFMT); and the Graduate Program in Civil Engineering at the Federal University of Bahia (PPEC-UFBA). The project also included the Innovation and Sustainability Platform for the Built Environment (PISAC) of UnB, linked to the university's Science and Technology Park (PCTec); the Laboratory for the Built Environment, Inclusion, and Sustainability (LACIS-UnB); the BIM Research and Project Development Environment of PISAC (PROBIM); and the Laboratory for Technology and Environmental Comfort at UFMT (LATECA).

PISAC focuses on innovation throughout all stages of the built environment life cycle, from conception, planning, construction, and operation, to repurposing or dismantling. PISAC develops collaborative networks to leverage consolidated technical capabilities at both national and international levels and conducts research in innovation, sustainability, and resilience within the built environment. One of

PISAC's key initiatives is PROBIM, which serves as a forum for discussion and knowledge consolidation, managing and developing projects that disseminate BIM-based methodologies in higher education contexts.

LACIS-UnB is dedicated to research, teaching, and outreach, with an emphasis on innovation and sustainability in the built environment. It promotes collaborative networks, social inclusion, environmental education, and the advancement of learning within the construction industry and related sectors. LACIS is committed to creating, testing, and sharing technologies and methodologies that support the construction industry's production chain, focusing on both processes and products.

LATECA-UFMT is a multipurpose environment designed for teaching, research, outreach, and technical services related to the management, technologies, impacts, and innovations of the built environment in both urban and rural contexts. Its mission includes promoting sustainability, performance, resilience, and habitability throughout the life cycle of buildings. It serves as a hub of technological innovation, aiming to transform the construction industry's production chain and is part of the Sustenta Network—a collaborative infrastructure that unites Brazilian public institutions in pursuit of sustainable built environments.

LIST OF ABBREVIATIONS

Acronym	Term
AP	Preliminary Design
BEP	BIM Execution Plan
BCF	BIM Collaboration Format
BDS	Building Description System
BIM	Building Information Modeling
BSI	British Standards Institution
CAD	Computer-Aided Design
CDE	Common Data Environment
COBie	Construction Operations Building Information Exchange
DSR	Design Science Research
FAET-UFMT	Faculty of Architecture, Engineering, and Technology - Federal University of Mato Grosso
FAPDF	Federal District Research Support Foundation
FAU	Faculty of Architecture and Urbanism
FT	Faculty of Technology
HBIM	Heritage Building Information Modeling
IFC	Industry Foundation Classes
LACIS	Laboratory for the Built Environment, Inclusion, and Sustainability – UnB
LATECA	Laboratory for Technology and Environmental Comfort – UFMT
LIM	Landscape Information Modeling
LOD	Level of Development

LV	Survey
PCTec	Science and Technology Park – UnB
PIM	Project Information Model
PISAC	Innovation and Sustainability Platform for the Built Environment – UnB
PN	Design Brief
PPEC-UFBA	Graduate Program in Civil Engineering – Federal University of Bahia
PROBIM	BIM Research and Project Development Environment – PISAC
UnB	University of Brasília
UFMT	Federal University of Mato Grosso
UFBA	Federal University of Bahia

SUMÁRIO

INTRODUCTION

Old buildings—whether classified as historic or not—often present inadequate conditions of operability and habitability, particularly in relation to sanitation, thermal comfort, visual and acoustic performance provided to users. These issues may stem from non-compliance with current regulations and standards that were not in force at the time of construction. Furthermore, over time, materials tend to deteriorate, and building systems become obsolete or damaged.

Nonetheless, such constructions often hold significant social and historical value for the communities in which they are located. It is therefore essential to identify ways to renovate and modernize them so that they can continue to be used appropriately and safely. This is where the concept of retrofit comes into play, understood as a set of actions aimed at modernizing and upgrading existing structures to make them more efficient and better suited to present-day needs. This concept emerged in the late 1990s in the United States and Europe, initially applied in the aerospace industry to refer to the upgrading of aircraft with newly available equipment. Over time, the term was adopted in the construction industry to designate modernization processes for buildings.

It is also known that retrofit practices are increasingly being integrated with Building Information Modeling (BIM) tools to support functions such as energy simulation and life cycle assessment, among others. For buildings that have not yet been modeled, drones and laser scanners are frequently used as alternatives for surveying and digitally reconstructing the geometry. BIM proves to be especially relevant when applied to historic buildings and heritage areas, since these technologies allow for the collection of detailed and characteristic data using point cloud modeling techniques.

However, in Brazil, studies on retrofit are still limited and fragmented. Many research efforts focus on specific aspects, such as energy efficiency, while neglecting other critical building systems. This results in a knowledge gap that hampers effective planning and execution of retrofit projects. BIM, in this context, presents itself as a high-potential solution, enabling the creation of precise digital models.

The use of BIM as a project methodology has grown significantly over the past decade, particularly in the development of integrated building designs, responding efficiently and accurately to the demands of the construction and real estate sectors. However, there is still a need to adapt this methodology, especially to address site-specific considerations and interventions in existing buildings. Thus, this manual presents the results of a research project that sought to explore the mechanisms for applying the BIM methodology in retrofit proposals and, based on this investigation, provide guidelines for carrying out retrofit interventions through BIM-based processes, while offering methodological contributions to support the dissemination of this practice in the Federal District.

For the development of this manual, the research strategy adopted was Design Science Research (DSR), as it is an investigative method that seeks to develop and design solutions to improve existing systems, solve problems, or create new artifacts that enhance human performance in societal or organizational contexts. Such artifacts can be defined as artificial objects characterized by their objectives, functions, and adaptability. They may take the form of Constructs, Models, Methods, or Instantiations.

In DSR, the researcher draws upon scientific knowledge to understand practical problems and prescribe appropriate solutions, acting not only as an observer but also as the builder and evaluator of the artifact. In this study, the developed artifact corresponds to a method, which is presented in this manual and guides the development of integrated retrofit projects through the use of BIM. According to typological classifications of DSR artifacts, this can be defined as a Method that is operationalized through an Instantiation—i.e., the application of an artifact in a real-world environment, demonstrating its feasibility and effectiveness.

The DSR approach followed the methodologies of Vaishnavi and Kuechler (2015) and Van Aken and Berends (2018), which propose a five-phase cycle for artifact development. The first phase is awareness, involving a comprehensive review of the current state of the subject and the identification of problems through literature analysis. The second phase is suggestion, which includes exploratory field studies and practical testing of tools and processes, resulting in a preliminary proposal. The third phase is development, during which the scope of the proposed method is refined through case studies. The fourth phase is evaluation, focusing on the assessment of both the method and its implementation outcomes, including the definition of research constructs and variables. The final phase is conclusion, which entails formalizing the proposed method, including its final structure and recommendations for implementation.

Following this framework, the development of this manual was structured in five phases. Literature review extended throughout the study, providing theoretical foundations for problem comprehension and artifact design, as well as allowing reflection on the contribution to scientific advancement. Additionally, during the awareness and suggestion phases, a systematic literature review was conducted to identify research gaps and clarify the theoretical contribution of this work.

The results presented here stem from a structured methodology that began with defining the problem class and artifact typology. The method and the manual were then conceived through participatory workshops aimed at making them more accessible and understandable for various stakeholders in the construction sector. These insights informed the iterative development of both the method and the manual. Finally, the proposed method was evaluated through its application in a pilot project, enabling rigorous assessment of its effectiveness and real-world applicability. This methodological approach ensures that the method presented in this manual not only addresses the sector's practical challenges but also provides a useful and effective tool for its intended users.

In conclusion, the final phase involves the general formalization of the process and the identification of its contributions to foster dialogue among academic, professional, and governmental communities. Chief among these contributions is the manual itself, which aims to guide professionals in developing retrofit projects using BIM, based on the outcomes of the pilot study.

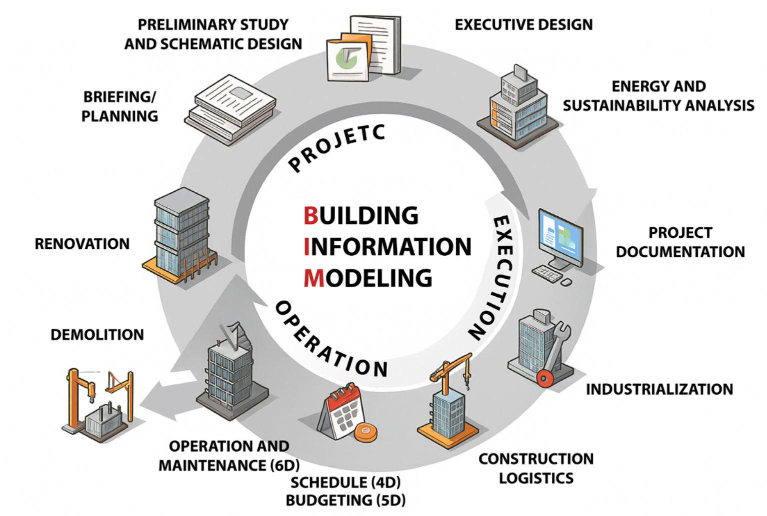
INITIAL CONCEPTS

This section presents key foundational concepts, divided into two main topics. The first introduces general definitions related to Building Information Modeling (BIM), its scope within managerial processes, a brief historical overview, as well as its collaborative and interoperability features. The second topic focuses on general concepts of retrofit and offers a preliminary discussion of the relevance of BIM in the development of such projects.

WHAT IS BIM?

The concept of BIM originated from 3D CAD (Computer-Aided Design) models and can be seen as an evolution of the Building Description System (BDS) proposed by Eastman and collaborators in 1974. In 1999, Eastman defined BIM as a process for managing the flow of information involved across the various phases of a building's life cycle (Figure 01), using a parametric digital model (based on virtual objects) that represents the physical and functional characteristics of the built asset.

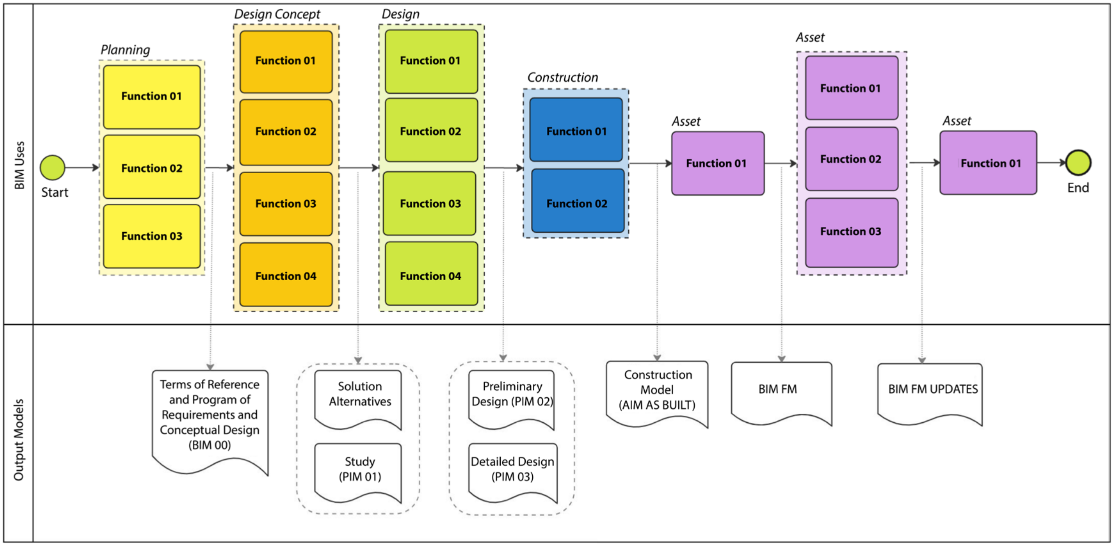
Figure 01: Representation of BIM throughout different phases of the building lifecycle.



In a generic work context, it is possible to identify several phases in which BIM can be applied, as well as a variety of functions it can serve. Figure 02 presents a typical life cycle organized in the phases of Planning, Conceptual Design, Project Design, Construction, and Asset (Operation and

Figure 01 Available at <https://www.emaze.com/@AQWRZFIC/BIM>, acesso em abril 2024.

Figure 02: Illustration of a generic project lifecycle.



Maintenance). Within each phase, distinct groups of functions define the use of modeling software. It is important to note that these functions often occur simultaneously and complementarily within the same phase and are interconnected by delivery milestones (for both internal project teams and clients).

In this general project life cycle, it is possible to identify expected output models at each phase. For example:

- PIM 00 results from the Planning phase

- Alternative Solutions and PIM 01 from the Conceptual Design phase
- PIM 02 and 03 from the Project Design phase
- AIM As-Built from the Construction phase
- BIM FM from the Asset Operation phase

The use of BIM offers a wide range of significant benefits for construction and project management professionals. It enables the creation of detailed digital building models, facilitating the visualization and understanding of all architectural and engineering components. Moreover, BIM enhances interdisciplinary collaboration, allows early detection of design conflicts, supports advanced analysis and simulations, enables change management, reduces errors and additional costs during construction, and simplifies long-term building maintenance. In short, BIM provides an integrated and effective approach to building design, construction, and management, resulting in more efficient, collaborative, and sustainable projects.

Effective collaboration among project stakeholders is essential to ensure high-quality standards and optimize the collective knowledge and experience of the team. Collaborative environments, as defined by the British Standards Institution (BSI), require efficient communication and data sharing to avoid loss, contradictions, or misinterpretations. This approach demands mutual understanding and trust among all team members, in addition to standardized processes for consistent and timely information production and delivery. The successful implementation of these methods depends on clearly defined roles and responsibilities and the establishment of a Common Data Environment (CDE).

Within the CDE, information from each project discipline progresses through different statuses—from “work in progress” to “archived”—as proposed by BSI. To ensure effective collaboration, technical data exchange standards such as Industry

Foundation Classes (IFC) and BIM Collaboration Format (BCF) are adopted to promote interoperability between software platforms and facilitate project coordination. Furthermore, practical methods like the Construction-Operations Building Information Exchange (COBie) support the sharing of structured data for operation and maintenance purposes, although they may require considerable cost and time investments. The core value of BIM lies in its ability to attribute meaningful information to the model, transforming workflows and collaboration through constant system interconnectivity.

WHAT IS RETROFIT?

The concept of retrofit began gaining traction in the late 1990s in the United States and Europe. Initially used in the aerospace industry to describe aircraft modernization using new equipment, the term was later adapted to the construction sector to refer to the updating of buildings to make them more contemporary. This process involves incorporating new technologies and tools to enhance a building's energy efficiency, natural resource management, structural resilience, operational performance, air quality, and user comfort. In summary, retrofit refers to the partial or full renewal of an existing building, offering an opportunity to improve its technical performance and promote sustainability.

For many experts, the greatest challenge in the dissemination of retrofit practices lies in the complexity of the technical processes involved (ZHANG et al., 2012; MAY; RYE, 2012; ÁSTMARSSON; JENSEN; MASLESA, 2013; DAUDA; AJAYI, 2022). From feasibility analysis to building occupancy, various steps must be carefully planned and executed. These include assessing the current state of the building, preparing project documentation, estimating costs, addressing legal requirements, and more. Interventions commonly focus on renovating electrical, plumbing, enclosure, and HVAC systems, often due to failures or inefficiencies in the original systems. These processes are further complicated by limited technological resources and a shortage of specialized labor. BIM, as noted by some researchers, can be a valuable tool in overcoming these barriers (SARDROUD et al., 2018; HOSSAIN; YEOH, 2018; D'ANGELO et al., 2022), by enabling more accurate cost estimates, energy savings, and improved stakeholder collaboration, data sharing, and overall project coordination.

THE IMPORTANCE OF BIM IN RETROFIT PROJECT DEVELOPMENT

In recent years, BIM has gained increasing prominence in the construction sector due to its various benefits and its potential for resource savings throughout the entire building life cycle. In consolidated urban areas, the construction sector has increasingly focused on renovation, retrofit, and even deconstruction of existing buildings. This shift has driven the development of tools and methodologies that allow for more precise analysis of building characteristics, from the initial design and planning phases through to post-occupancy, with BIM playing a central role.

BIM is regarded as an advanced modeling and process integration tool, enabling the creation, communication, and analysis of digital building models that can be managed, shared, and exchanged in an interoperable manner. It is widely believed that BIM provides valuable tools for all aspects of project management, involving all stakeholders across all life cycle stages.

Although many professionals assume that BIM is limited to the early stages of a building's life cycle and ends after construction, there is growing recognition of its potential for supporting retrofit projects. Retrofitting presents a range of challenges—from the lack of detailed documentation on existing buildings to technical difficulties in data collection, cost management, legal and organizational concerns, and ongoing maintenance. BIM has shown promise in addressing these challenges by improving cost management, enhancing stakeholder collaboration, and streamlining building maintenance over time. Nonetheless, obstacles remain, such as the scarcity of detailed documentation, including accurate floor plans and material and system specifications.

This manual seeks to provide clear guidance on conducting retrofit interventions through BIM-based processes, in response to the growing demand for such projects and the inherent challenges involved. It emphasizes the importance of structured information modeling methodologies tailored specifically for retrofit practices.

MANUAL STRUCTURE

AGENTS

Within the BIM workflow, the agents that make up the project team and their roles in each phase of the information life cycle are identified. The agents, their role descriptions, and their responsibilities are presented in Table 01.

PRODUCTS

The products are the results of activities carried out during the contracted project phase. It is important to note that, prior to contracting, the BIM workflow requires the Contracting Party to develop a Terms of Reference (BIM Mandate) and the Contracted Party to submit a Pre-contractual BIM Execution Plan, as described in Table 02.

Table 01 – Description of agent roles in the BIM-Retrofit Workflow

Agent	Description	Activities in the Workflow
Project Coordination	Responsible for the overall coordination of the project, ensuring compliance with objectives, deadlines, and established requirements.	Establishment of design procedures; Coordination and verification of Information Models; Development of authoring models; Building analysis; Deliverables analysis/validation; *Budgeting.
BIM Coordination	Responsible for BIM implementation in the project, management of the Common Data Environment (CDE), and efficient integration and coordination of models.	Establishment of design procedures; Coordination and verification of Information Models.
Reviewer	Responsible for verifying that the information produced in the models complies with the defined standards and requirements.	Coordination and verification of Information Models.

Agent	Description	Activities in the Workflow
BIM Author	Responsible for inputting information into the model by creating, developing, and maintaining detailed 3D models using specific BIM authoring software.	Development of Authoring Models for the Project Information.
Technical Consultant	Responsible for performing analyses and simulations on the building using model information and complementary data to support decision-making.	Building Analysis.
Analysts	Team linked to the contracting party, responsible for validating the modeled and inputted information and for quality control of deliverables	Deliverables Analysis.
Cost Estimator	Responsible for generating cost estimates based on information extracted from the models using BIM-compatible estimating software.	*Budgeting.
Builder	Responsible for executing the construction work.	*Building Construction.
Asset Manager	Responsible for managing and operating the built asset, as well as monitoring and updating the model.	*Building Use, Operation, and Maintenance.
Demolition Manager	Responsible for planning, managing, and executing the demolition process.	*Building Demolition.

*Note: Activities marked with * are not detailed in the workflow since the focus of the manual is on the design process.*

Table 02 – Description of products in the BIM-Retrofit Workflow

BIM MANDATE	Document in which the Contracting Party defines strategic guidelines and expected standards for all BIM projects.
BEP-PRE	Project plan submitted at the proposal stage, describing how the modeling and information processes will be executed.
BEP-POST	Project plan submitted after contracting, describing how information modeling will be carried out during service execution. This document may be updated throughout the project.
MIDP	Master Information Delivery Plan: defines what information is required, who will produce it, its format, and delivery schedule.
TIDP	Task Information Delivery Plan: defines information delivery schedules for each individual task.
PIM "AS IS"	Project Information Model that includes geometric and non-geometric information about the building's current state, supporting the retrofit design.
PIM 01, 02, AND 03	Project Information Models representing geometric and non-geometric information for each retrofit design phase: Preliminary Design (PIM 01), Design Development (PIM 02), and Construction Documentation (PIM 03).
AIM (AS BUILT)	Asset Information Model containing geometric and non-geometric data of the completed construction.
BIM FM	Asset Information Model focusing on the building's operation and maintenance.
BIM FM UPDATES	Updated Asset Information Model reflecting changes and maintenance records during operation.

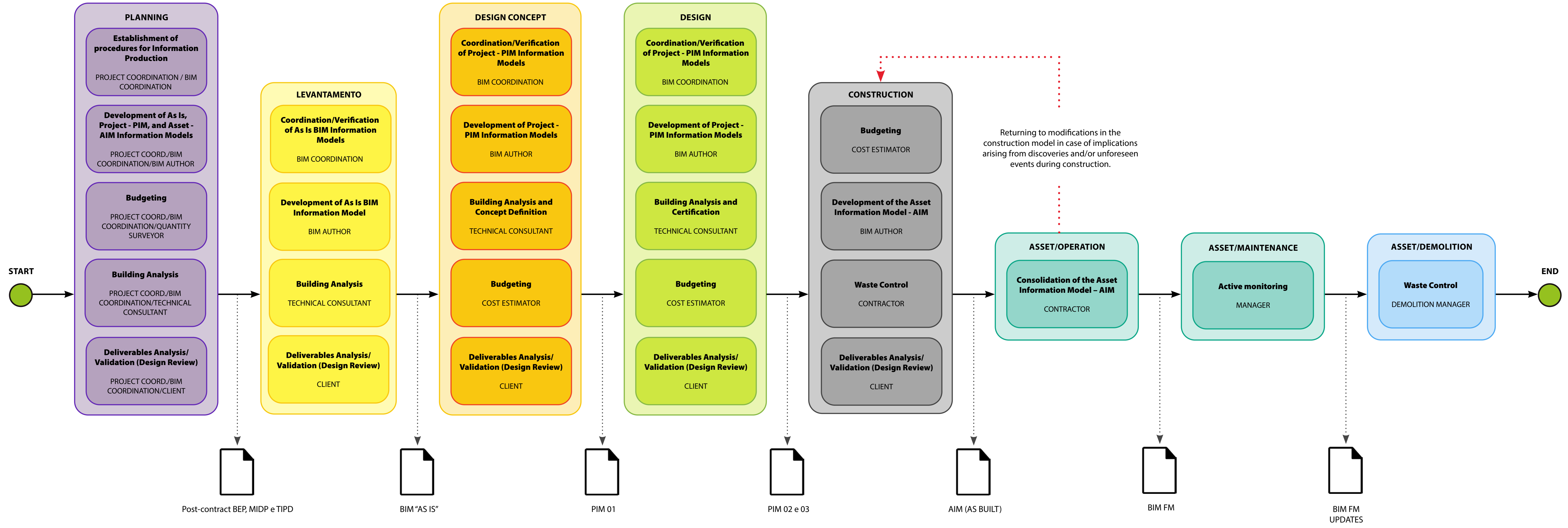
WORKFLOW ACROSS THE INFORMATION LIFE CYCLE PHASES

In a general work context, several distinct phases for the use of BIM can be highlighted, as well as the various functions to which it is applied. Figure 03 illustrates an information life cycle specifically tailored to the BIM-Retrofit workflow. This cycle is organized into the following phases:

- Planning
- Surveying
- Conceptual Design
- Project Design
- Construction
- Asset Operation
- Demolition

Within each phase, groups of functions are identified that correspond to the intended uses of BIM.

Figure 03: Workflow across the phases of the information lifecycle.



PLANNING PHASE

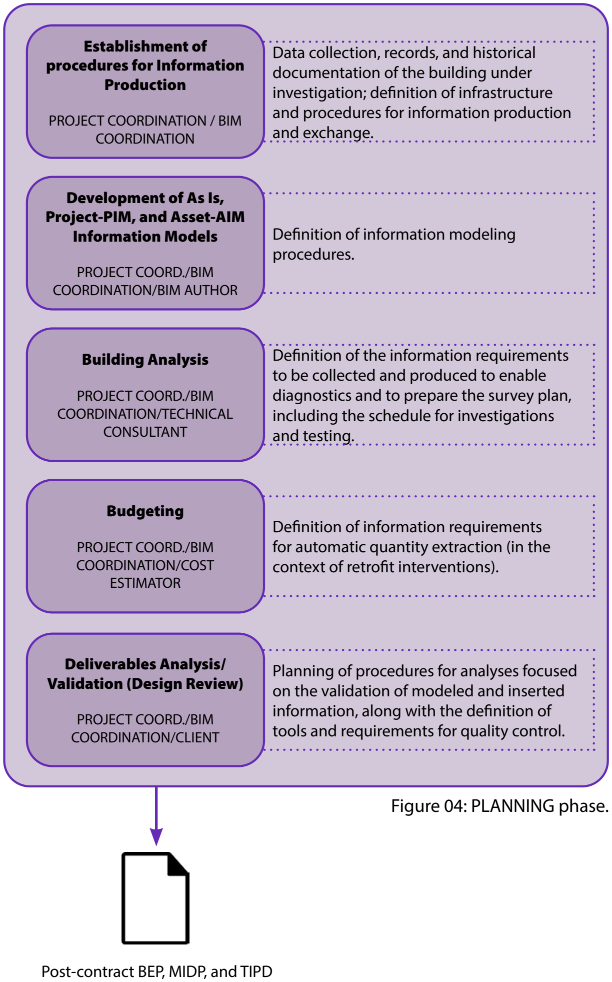


Figure 04: PLANNING phase.

In the Planning phase, the requirements, procedures, teams, and plans must be established, as well as the necessary infrastructure, and the procedures for information production and management must be tested. As a result, all activities outlined in the workflow presented in Figure 03 begin at this stage.

The role of the contracted design firm in obtaining approval for the deliverables through the Deliverables Analysis/ Validation process must be taken into account during this phase.

The BEP-Post (Post-Contract BIM Execution Plan), the MIDP (Master Information Delivery Plan), and the TIDP (Task Information Delivery Plan) are deliverables expected to be developed at this stage, along with all protocols and manuals that guide the teams in performing their various functions.

SURVEYING PHASE

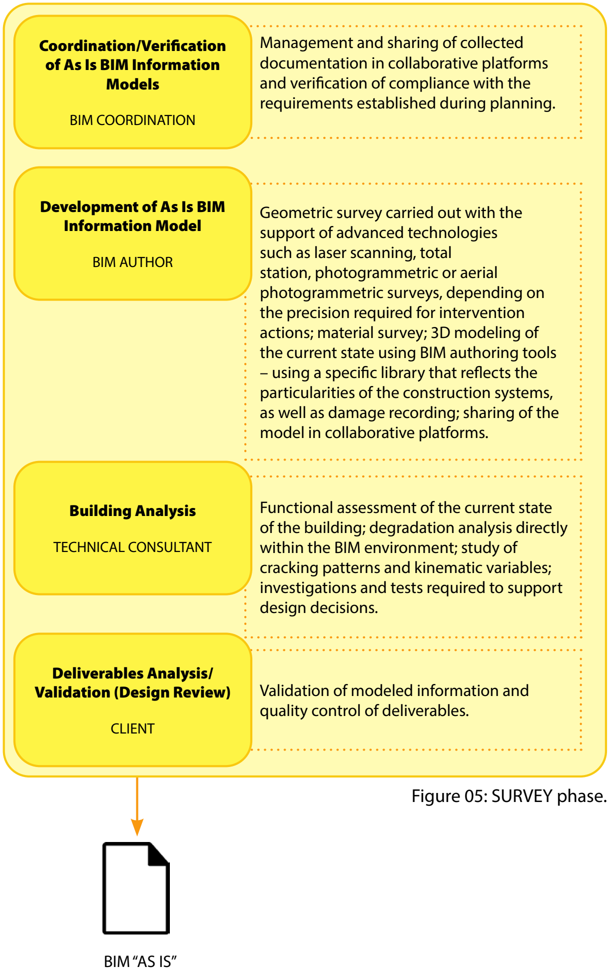


Figure 05: SURVEY phase.

In the Surveying phase, an advanced geometric and material survey must be conducted, followed by 3D modeling of the building's current state (BIM As Is) using BIM authoring tools. This phase also includes investigative activities that support design decision-making.

Within the responsibilities of the contracted design firm, the approval of the deliverables produced during this phase through the Deliverables Analysis/Validation process must be considered.

The Asset Information Model – AIM (BIM "As Is") and all survey records, diagnostics, and resulting documents are expected deliverables to be developed during this stage. In the case of historic buildings, this phase must include archaeological services encompassing planning, prospecting, monitoring, recovery, laboratory testing, preservation, and dissemination, in order to ensure the conservation of identified historical records, in accordance with the guidelines established by Ordinance No. 007 of December 1, 1988.

CONCEPTUAL DESIGN PHASE

In the Conceptual Design phase, the development and coordination of the project information model in the Preliminary Study stage must be carried out, based on the design concept (Partido) defined in the retrofit project and resulting from the Building Analysis activity.

Within the responsibilities of the contracted design firm during this phase, the approval of the deliverables produced must be considered through the Deliverables Analysis/Validation process.

The Project Information Model – PIM 01 (Preliminary Study), the cost estimation, and all records of the studies conducted are expected delive-

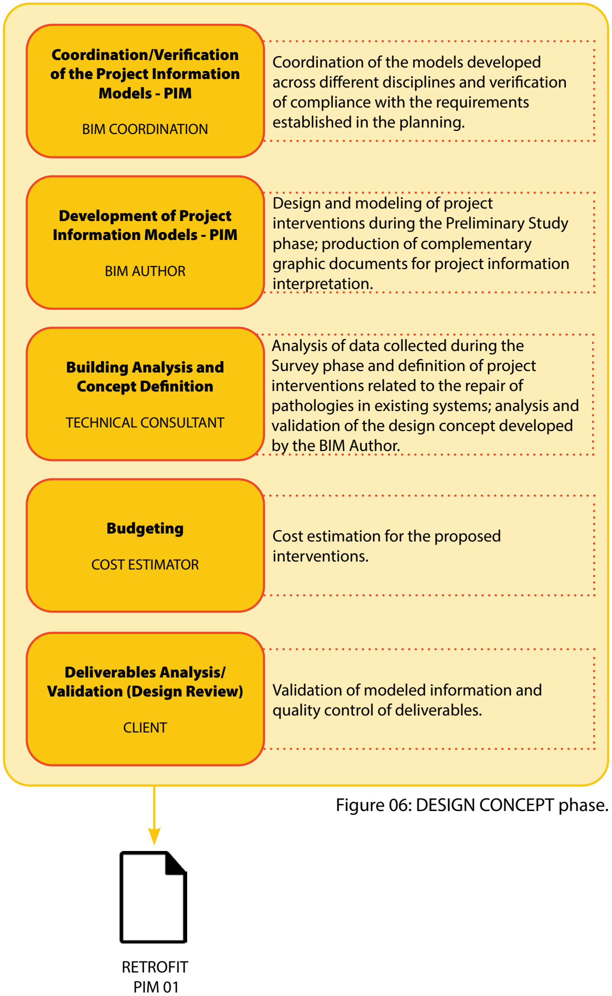


Figure 06: DESIGN CONCEPT phase.

rables to be developed at this stage.

PROJECT DESIGN

In the Project Design phase, the development of both legal designs (for approval by the relevant authorities) and executive designs (for the execution of retrofit services) must be carried out. These designs are structured to ensure the feasibility of the proposed interventions, and both are developed through the coordination of all models via a Common Data Environment (CDE). The executive design must be accompanied by a cost estimate, generated through BIM-based processes and tools.

In the case of historic buildings, archaeological services must be considered, with the role of providing guidance on the potential impact of executive design solutions on the building's preservation.

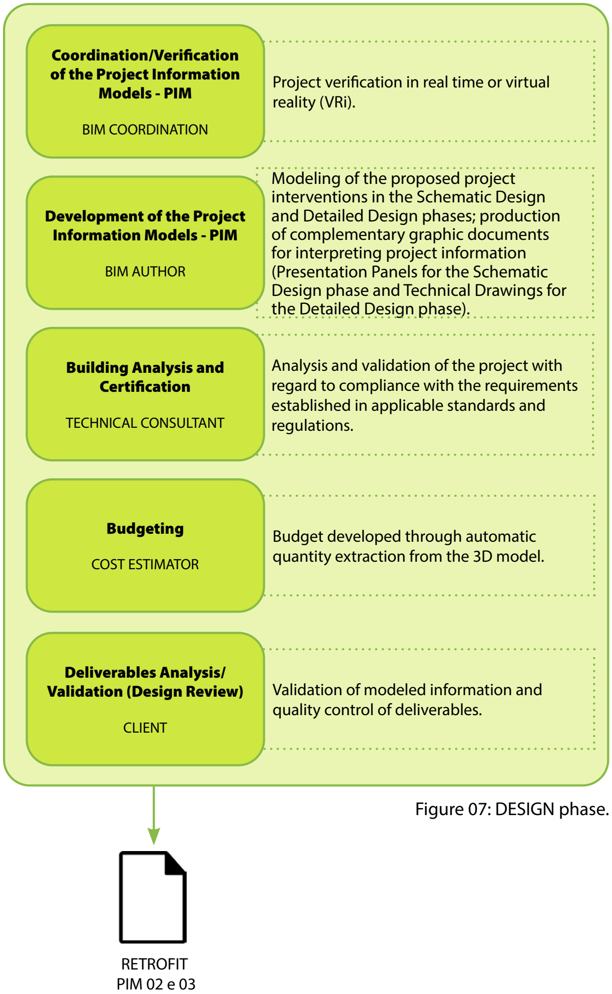


Figure 07: DESIGN phase.

Within the responsibilities of the contracted design firm, the approval of deliverables produced during this phase must be addressed through the Deliverables Analysis/Validation process.

The Project Information Models – PIM 02 and PIM 03 (Legal and Executive), the cost estimation, and all project documentation related to the development stages are expected outputs to be produced during this phase.

CONSTRUCTION

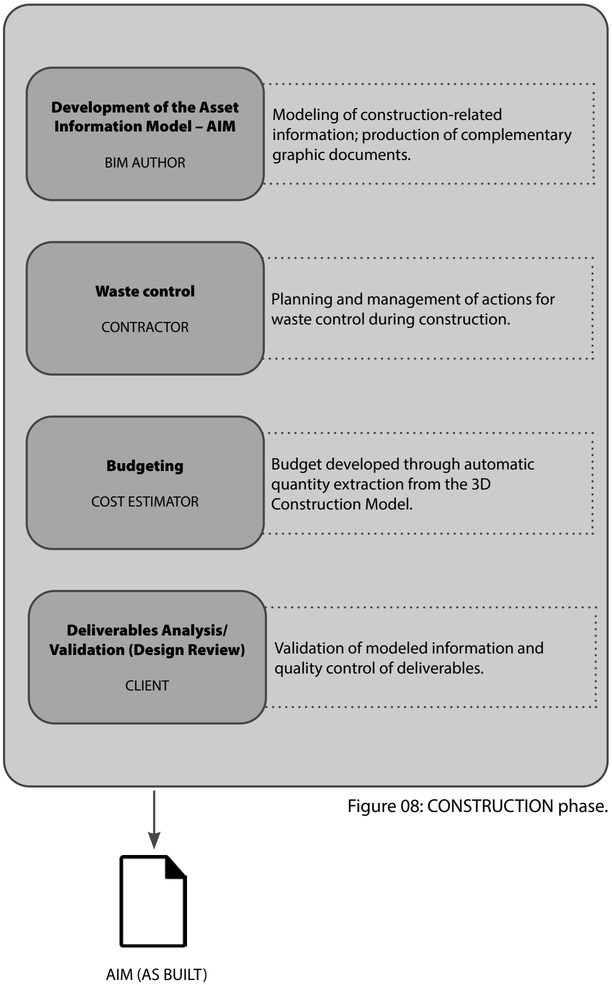


Figure 08: CONSTRUCTION phase.

In the Construction phase, the modeling of construction-related information must be carried out, as it is essential for enabling and planning the execution of the work. This model is developed under coordination through a Common Data Environment (CDE). The construction model must be accompanied by a cost estimate, which is generated using BIM tools. Additionally, it is necessary to develop a Waste Management Action Plan to be implemented during the construction phase.

In the case of historic buildings, archaeological services must monitor all intervention activities and, if required, perform planning, prospecting, monitoring, recovery, laboratory testing, preservation, and dissemination, in order to ensure the conservation of historical records.

The responsibilities of the contracted design firm during this phase must include ensuring the approval of the deliverables produced through the Deliverables Analysis/Validation process

The Asset Information Model – AIM (As Built), the cost estimation, and all documentation related to the construction process are expected outputs to be developed during this phase.

ASSET OPERATION AND MAINTENANCE

In the Asset Operation phase, the modeling of information produced during the construction of the existing building must be carried out, incorporating the activities required to maintain an adequate level of efficiency for the functions for which the building was designed.

Additionally, in the context of building use, information must be modeled regarding asset monitoring actions, as well as the recording and updating of maintenance activities and the updating/replacement of systems in operation.

The Asset Information Model – BIM-FM (Facility Management), its updates, and all documentation related to the operation and maintenance of the building are expected outputs to be developed during this phase.

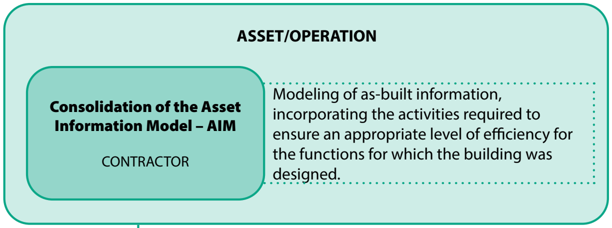
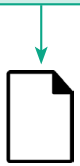


Figure 09: ASSET/OPERATION phase.



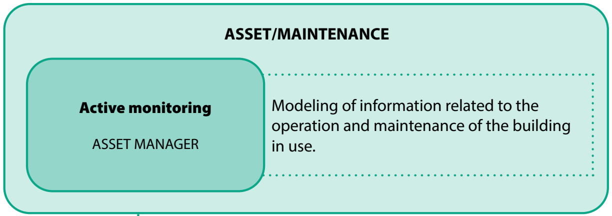
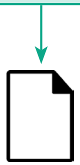


Figure 10: ASSET/MAINTENANCE phase.



ASSET DEMOLITION

In the Asset Demolition phase, the planning and management of actions for controlling the waste generated during the demolition process must be carried out.

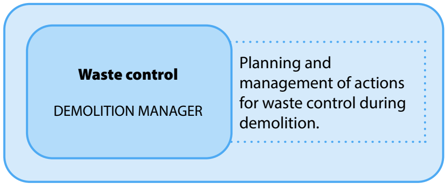


Figure 11: ASSET/DEMOLITION phase.

BIM WORKFLOW IN THE INFORMATION DELIVERY CYCLE

The workflows are carried out using a process modeling concept, also known as BPMN (Business Process Model and Notation). In the BPMN context, a process is an activity carried out by an organization and composed of a series of steps and controls that enable the flow of information. The most commonly used elements (Figure 12) to build it are: activities, events, gateways (decisions), and sequence flows or routes.

BPMN establishes a set of graphical elements intended to provide complementary information about the process—these are called artifacts. There are three standard types of artifacts: data objects (which provide information about the inputs and outputs of an activity), annotations (which allow the inclusion of comments about the process), and groups (which allow activities to be clustered for documentation or analysis purposes) (Figure 13).

Finally, there are connectors (Figure 14), which are lines that link activities, gateways, and events.

To facilitate the joint reading of different workflows and to distinguish what is generated by the BIM Coordination workflow from what is produced by other Agents, color variations were defined for the flow objects (Gateways), Artifacts (Data Objects), and connectors (Sequence Lines). The color blue was used for Gateways under BIM Coordination, red for those related to Deliverables Analysts, and green for Project Analysts (Figure 15).

The various workflows unfold in a simultaneous temporal context and are aligned at key decision points (Gateways), given that the flow pauses until a decision is made, defining the subsequent path of the model.

In the presentation of the workflow, the Gateways associated with the Deliverables Analyst are considered delivery milestones that guide the validation by the Client regarding compliance with the requirements underpinning the contract. The actions of the various project team agents, which consolidate

Figure 12: Representation of BPMN elements.

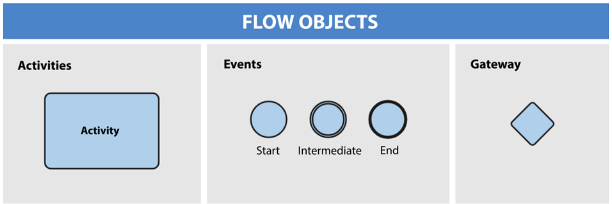


Figure 13: Representation of artifacts.

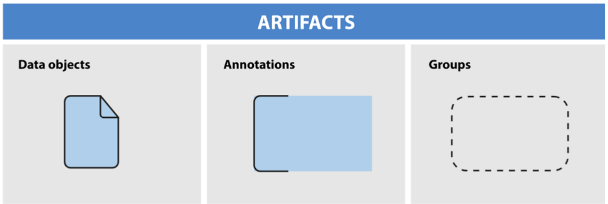


Figure 14: Representation of connecto.

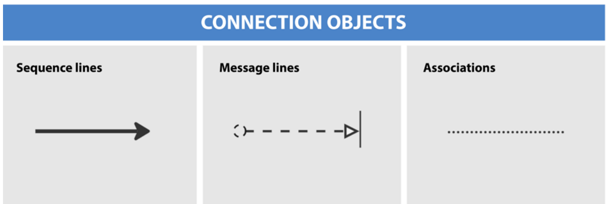
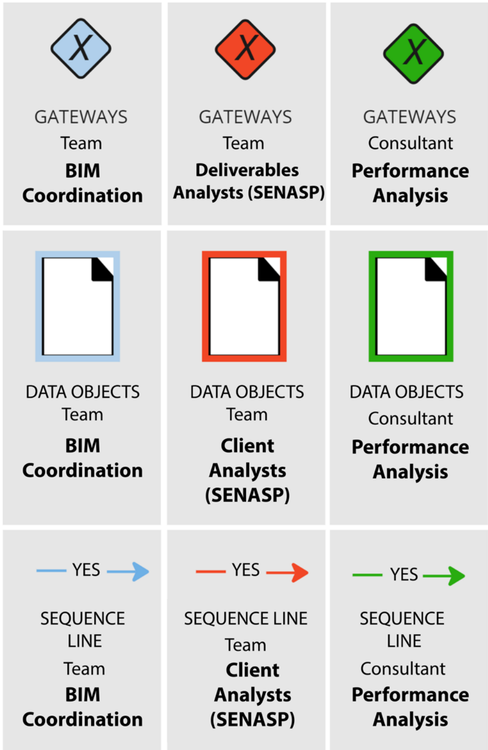


Figure 15: Configuration of Objects, Artifacts, and Connections with color distinctions used in the manual's flow illustrations.



the deliverable products at each milestone, are described in detail within the context of each task/delivery team.

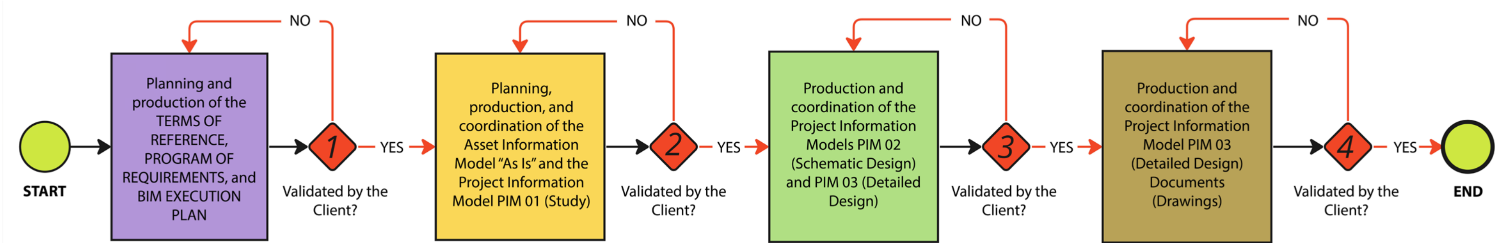
Delivery Milestone 1 encompasses the planning and products that precede the development of the Information Model (Terms of Reference, Requirements Program, BIM Execution Plan, and Field Survey Plan).

Delivery Milestone 2 encompasses the production of the information model resulting from the survey (As Is) and the Conceptual Model (PIM 01), as well as their coordination and verification.

Delivery Milestone 3 encompasses the production of the design information model in the Preliminary Design (PIM 02) and Detailed Design (PIM 03) phases, including their coordination and verification.

Delivery Milestone 4 encompasses the production of documents that support the interpretation of the project (Manuals, Technical Drawings, and Specifications), which are related to the design information model in the detailed design phase (PIM 03).

Figure 16: Representation of BPMN elements.



BIM WORKFLOW IN THE INFORMATION DELIVERY CYCLE

ESTABLISHMENT OF PROCEDURES FOR DESIGN AND COORDINATION AND VERIFICATION OF INFORMATION MODELS

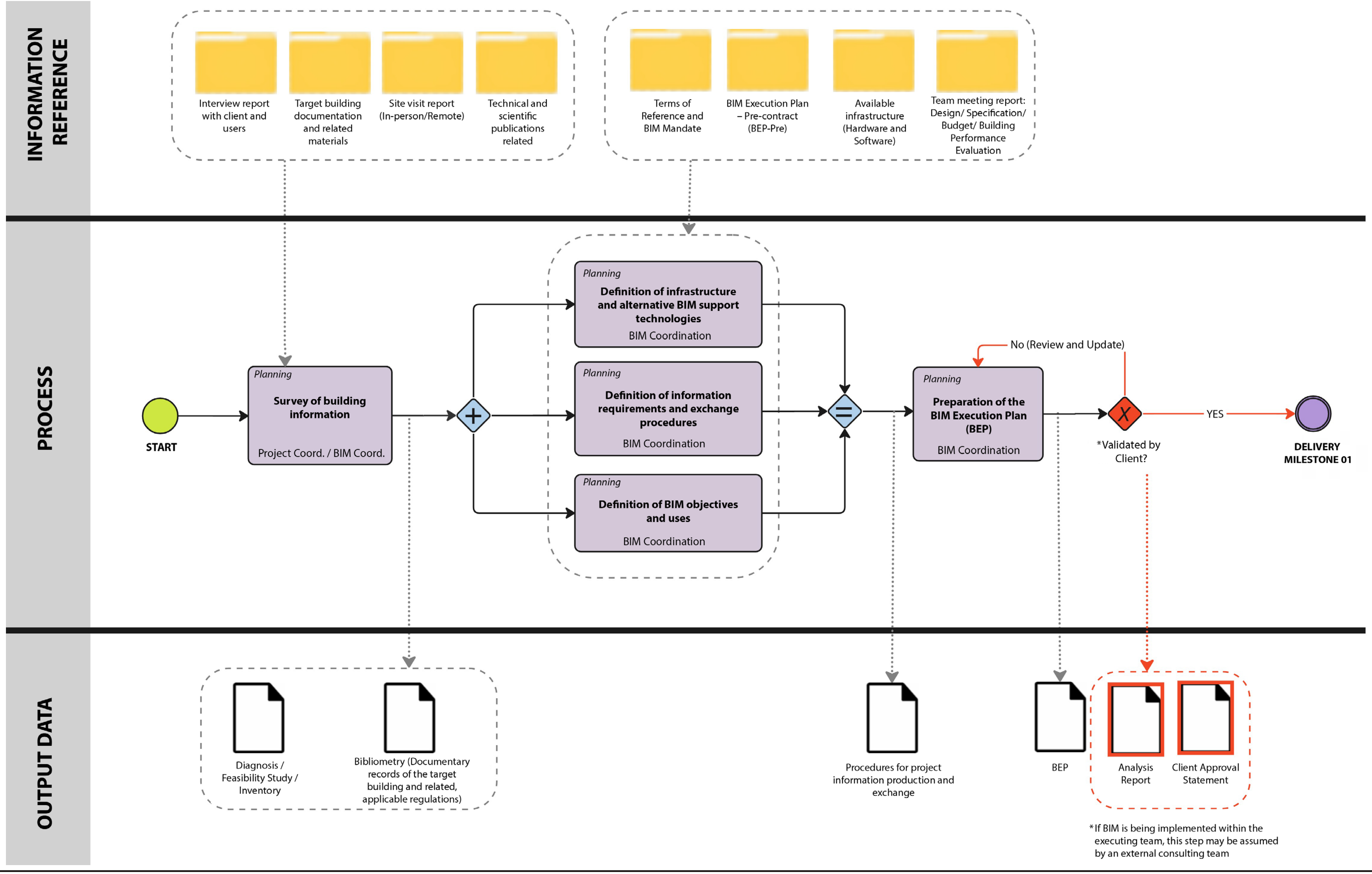
This initial information flow describes the activities related to the BIM Coordination agents during the planning phase. Within this flow, procedures for project development are established and subsequently updated throughout all phases of information development, in addition to encompassing the coordination and verification of information models. It is important to note that the construction, operation and maintenance, and demolition phases are not addressed in this flow.

Delivery Milestone 1

The establishment of procedures for design is carried out during the Planning phase, encompassing activities such as Data Collection, Consolidation of Procedures and Infrastructure, Definition of Information Requirements, Team Training, and Development of the BIM Execution Plan (BEP) Project. Reference documents for this stage include materials related to the preliminary information survey of the building, the BIM Mandate, and the Pre-contractual BEP, among others.

The outcomes of this activity include the BIM Protocols and Manuals, which provide guidance on modeling and information exchange procedures according to the intended functions of the models, as well as the BIM Execution Plan (BEP), which must be validated by the client

Although this phase does not involve modeling activities per se, it is when the tools and software are tested and the necessary infrastructure is prepared to support project development. The information used during this stage is derived from the investigation of the project typology, team meeting reports, and the Organization's Information Requirements.


INFORMATION REFERENCE
PROCESS
OUTPUT DATA
Interview report with client and users
Target building documentation and related materials
Site visit report (In-person/Remote)
Technical and scientific publications related
Terms of Reference and BIM Mandate
BIM Execution Plan – Pre-contract (BEP-Pre)
Available infrastructure (Hardware and Software)
Team meeting report: Design/ Specification/ Budget/ Building Performance Evaluation
START
Planning
Survey of building information
Project Coord. / BIM Coord.
Planning
Definition of infrastructure and alternative BIM support technologies
BIM Coordination
Planning
Definition of information requirements and exchange procedures
BIM Coordination
Planning
Definition of BIM objectives and uses
BIM Coordination
Planning
Preparation of the BIM Execution Plan (BEP)
BIM Coordination
No (Review and Update)
*Validated by Client?
YES
DELIVERY MILESTONE 01
Diagnosis / Feasibility Study / Inventory
Bibliometry (Documentary records of the target building and related, applicable regulations)
Procedures for project information production and exchange
BEP
Analysis Report
Client Approval Statement
*If BIM is being implemented within the executing team, this step may be assumed by an external consulting team

Delivery Milestone 2

Following validation by the client, the second delivery milestone begins—still within the Planning phase—during which the activities of BIM Protocol Development and Review Tool Setup take place, in addition to Team Integration Workshops.

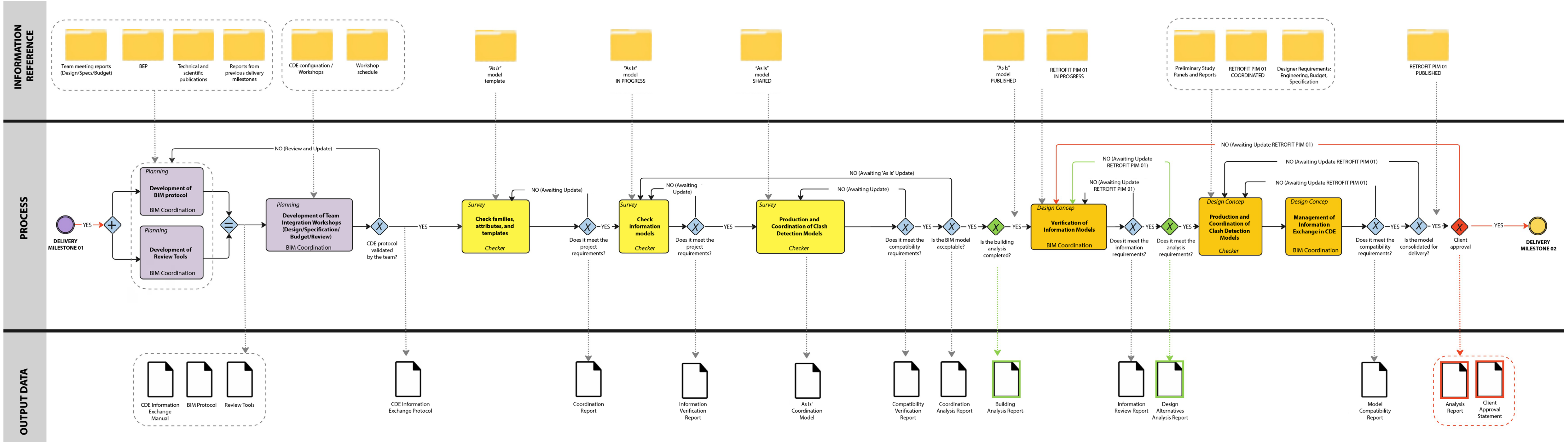
During the Survey phase, the following activities are interconnected: Verification of Families, Attributes and Templates; Verification of Authoring Information Models; Production of the Coordination Model; and the Conformance Analysis, which is then generated. These outputs are validated by the coordination team and move forward into the Design phase.

The outcomes of this stage include: the BIM Protocol, Review Tools, the Information Exchange Protocol, Coordination Reports, Information Verification Reports, the "As Is" Coordination Model, and the Compatibility Verification and Coordination Analysis Report.

It is recommended that all information exchange—whether between different teams or within the same team—be carried out through a Common Data Environment (CDE), enabling simultaneous but controlled access to a database containing information from all disciplines involved.

In the Design phase, BIM Coordination is responsible for managing the exchange of information regarding the project alternatives proposed by the BIM Authors. This management results in the Alternative Analysis Reports and Model Compatibility Reports, which guide the BIM Authors in the adjustment and coordination of information within the models. The Coordination team then validates and verifies whether the model is consolidated for delivery; if so, it is submitted for client approval.

It is important to emphasize the need to include, in the BIM project development schedule, the process of information maturation within the models, since the information production cycle restarts with each verification round. However, this only occurs if inconsistencies are identified in relation to the requirements defined during the Planning phase.

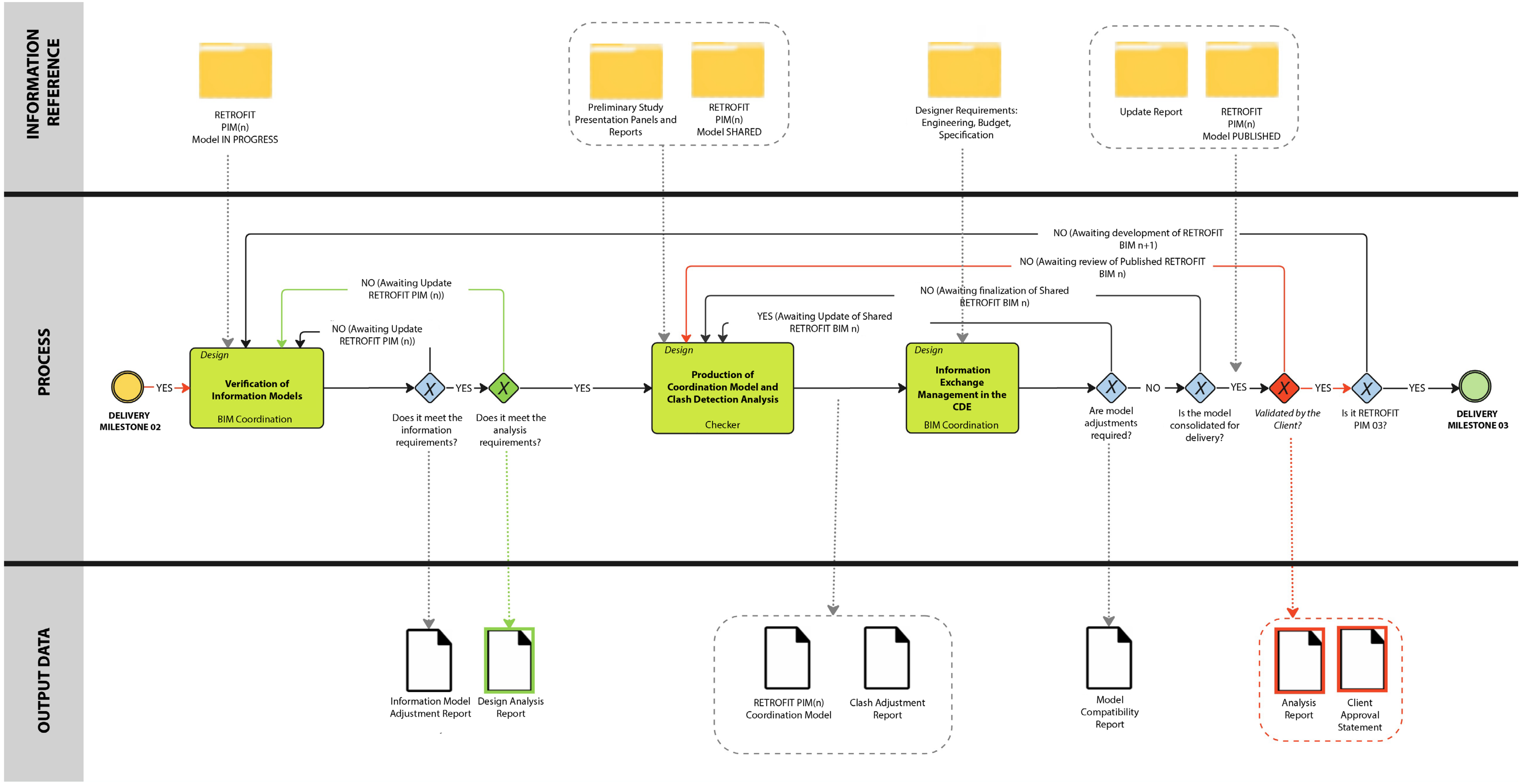

INFORMATION REFERENCE
PROCESS
OUTPUT DATA
Team meeting reports (Design/Specs/Budget)
BEP
Technical and scientific publications
Reports from previous delivery milestones
CDE configuration / Workshops
Workshop schedule
"As is" model template
"As Is" model IN PROGRESS
"As Is" model SHARED
"As Is" model PUBLISHED
RETROFIT PIM 01 IN PROGRESS
Preliminary Study Panels and Reports
RETROFIT PIM 01 COORDINATED
Designer Requirements: Engineering, Budget, Specification
RETROFIT PIM 01 PUBLISHED
DELIVERY MILESTONE 01
YES
Planning
Development of BIM protocol
BIM Coordination
Planning
Development of Review Tools
BIM Coordination
NO (Review and Update)
Planning
Development of Team Integration Workshops (Design/Specification/ Budget/Review)
BIM Coordination
CDE protocol validated by the team?
YES
Survey
Check families, attributes, and templates
Checker
NO (Awaiting Update)
Does it meet the project requirements?
YES
Survey
Check information models
Checker
NO (Awaiting Update)
Does it meet the project requirements?
YES
NO (Awaiting 'As Is' Update)
Survey
Production and Coordination of Clash Detection Models
Checker
NO (Awaiting Update)
Does it meet the compatibility requirements?
YES
Is the BIM model acceptable?
YES
Is the building analysis completed?
YES
NO (Awaiting Update RETROFIT PIM 01)
NO (Awaiting Update RETROFIT PIM 01)
NO (Awaiting Update RETROFIT PIM 01)
Design Concep
Verification of Information Models
BIM Coordination
Does it meet the information requirements?
YES
Does it meet the analysis requirements?
YES
NO (Awaiting Update RETROFIT PIM 01)
NO (Awaiting Update RETROFIT PIM 01)
Design Concep
Production and Coordination of Clash Detection Models
Checker
Design Concep
Management of Information Exchange in CDE
BIM Coordination
Does it meet the compatibility requirements?
YES
Is the model consolidated for delivery?
YES
Client approval
YES
DELIVERY MILESTONE 02
CDE Information Exchange Manual
BIM Protocol
Review Tools
CDE Information Exchange Protocol
Coordination Report
Information Verification Report
As Is' Coordination Model
Compatibility Verification Report
Coordination Analysis Report
Building Analysis Report
Information Review Report
Design Alternatives Analysis Report
Model Compatibility Report
Analysis Report
Client Approval Statement

Delivery Milestone 3

In the Design phase, the primary role of BIM Coordination is to verify the RETROFIT PIM(n) Information Models developed by the BIM Authors. Initially, the Coordination team checks whether the models meet the information requirements established in the BEP; if so, they proceed to the production of the Coordination Model and to Clash Detection Analysis. Only after being approved by the coordination team, and if considered complete, is the model forwarded for client approval.

Due to the high volume of information generated by various teams—or even within the same team—it is recommended that all information exchange be managed by the BIM Coordination team through the Common Data Environment (CDE).

The outcomes of this activity include Adjustment Reports for the Information Model, which guide the BIM Authors in adapting the Coordination Models PIM 02 and PIM 03, as well as Model Compatibility Reports, which in turn direct the BIM Authors in aligning the information within the models.

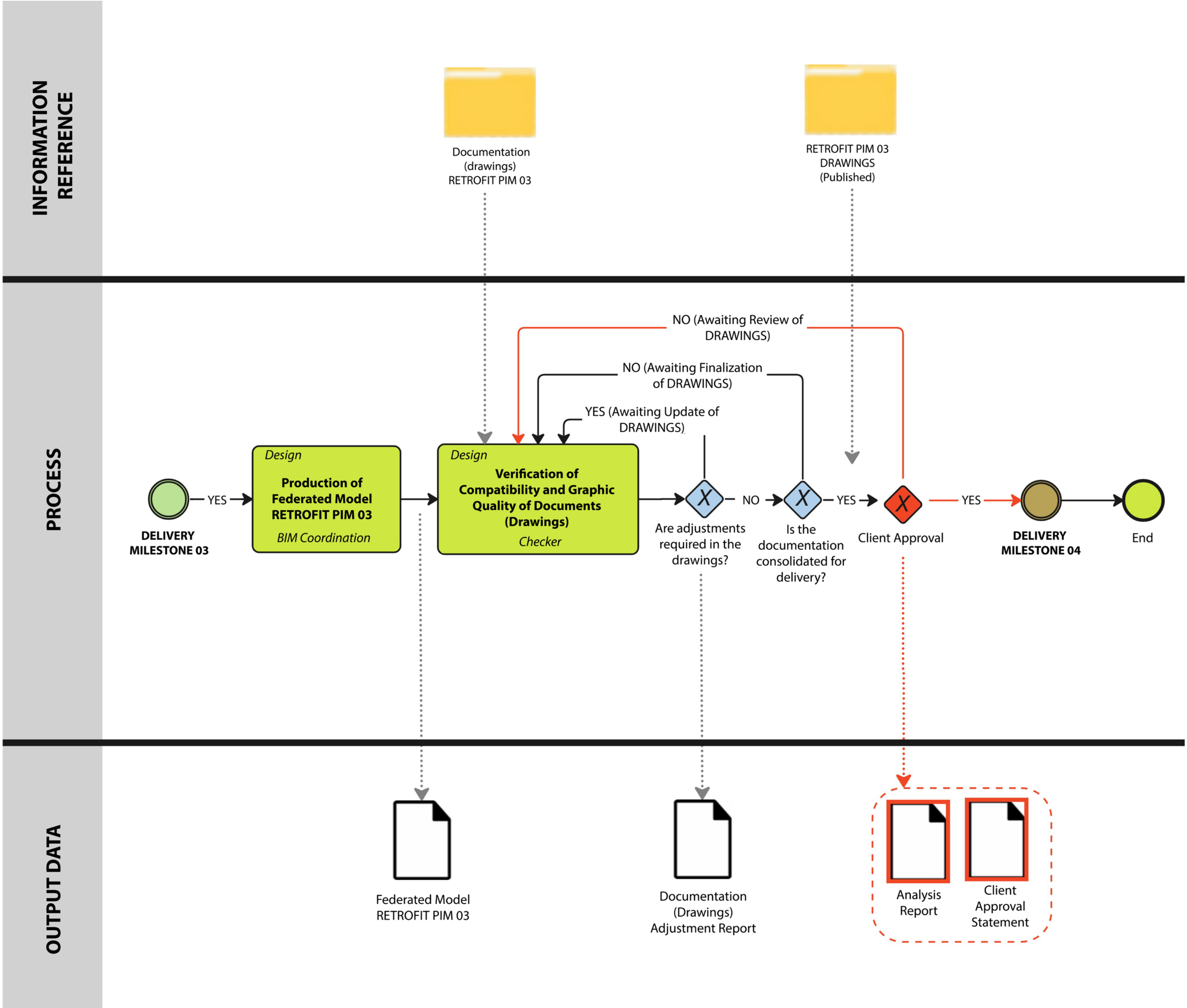

INFORMATION REFERENCE
PROCESS
OUTPUT DATA
RETROFIT PIM(n) Model IN PROGRESS
Preliminary Study Presentation Panels and Reports
RETROFIT PIM(n) Model SHARED
Designer Requirements: Engineering, Budget, Specification
Update Report
RETROFIT PIM(n) Model PUBLISHED
NO (Awaiting development of RETROFIT BIM n+1)
NO (Awaiting review of Published RETROFIT BIM n)
NO (Awaiting finalization of Shared RETROFIT BIM n)
YES (Awaiting Update of Shared RETROFIT BIM n)
NO (Awaiting Update RETROFIT PIM (n))
NO (Awaiting Update RETROFIT PIM (n))
DELIVERY MILESTONE 02
YES
Design
Verification of Information Models
BIM Coordination
YES
Does it meet the information requirements?
Does it meet the analysis requirements?
YES
Design
Production of Coordination Model and Clash Detection Analysis
Checker
Design
Information Exchange Management in the CDE
BIM Coordination
Are model adjustments required?
NO
Is the model consolidated for delivery?
YES
Validated by the Client?
YES
Is it RETROFIT PIM 03?
YES
DELIVERY MILESTONE 03
Information Model Adjustment Report
Design Analysis Report
RETROFIT PIM(n) Coordination Model
Clash Adjustment Report
Model Compatibility Report
Analysis Report
Client Approval Statement

Delivery Milestone 4

After the third delivery milestone, the coordination team verifies whether the Information Model corresponds to PIM 03, that is, whether it pertains to the final stage of the detailed design phase. If so, the process continues with the development of the Federated RETROFIT PIM 03 Model. A graphic and information compatibility check of the documents (drawings, specifications, and supporting materials) is then carried out. Only after validation against the requirements established in the BEP and in applicable standards does the workflow proceed to final client approval.

In this case, the reference information consists of the RETROFIT PIM 03 documentation, and the reference deliverables include the Federated PIM 03 Model and the Adjustment and Documentation Report.

As in previous stages, it is essential that the BIM project development schedule anticipates the process of information maturation within the documents, since the information production cycle restarts with each verification round by both the BIM Coordination and the Client. However, such modifications should only occur if inconsistencies are identified in relation to the previously defined requirements.


INFORMATION REFERENCE
PROCESS
OUTPUT DATA
Documentation (drawings) RETROFIT PIM 03
RETROFIT PIM 03 DRAWINGS (Published)
NO (Awaiting Review of DRAWINGS)
NO (Awaiting Finalization of DRAWINGS)
YES (Awaiting Update of DRAWINGS)
DELIVERY MILESTONE 03
YES
Design
Production of Federated Model RETROFIT PIM 03
BIM Coordination
Design
Verification of Compatibility and Graphic Quality of Documents (Drawings)
Checker
Are adjustments required in the drawings?
NO
Is the documentation consolidated for delivery?
YES
Client Approval
YES
DELIVERY MILESTONE 04
End
Federated Model RETROFIT PIM 03
Documentation (Drawings) Adjustment Report
Analysis Report
Client Approval Statement

DEVELOPMENT OF PROJECT INFORMATION MODELS

This information flow describes the activities related to the development of the information model, both for the Project and for the Asset, and involves the participation of the Project Coordination agents, BIM Authors, and BIM Modelers.

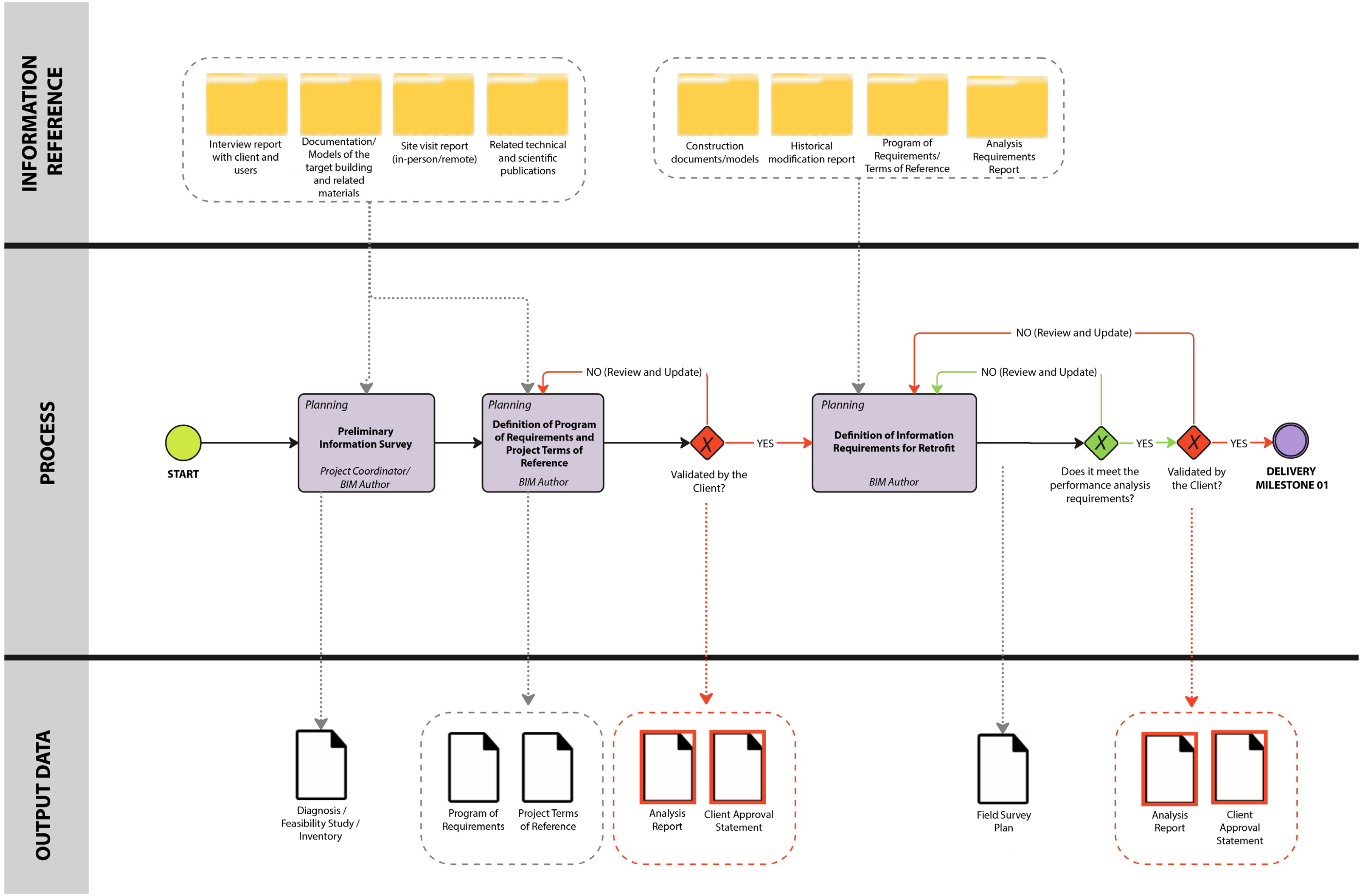
It covers the Planning, Survey, Design Concept, and Design phases, encompassing the definitions of the Requirements Program, Terms of Reference (TR), Solution Studies (Design Concept), Asset Information Model (As Is), Preliminary Study PIM 01, Schematic Design PIM 02, and Detailed Design PIM 03.

Delivery Milestone 1

Authoring information models do not always result in three-dimensional geometric solutions, especially in the early phases of the project, when geometry has not yet been defined. This is the case for the outputs generated during the Planning phase. The activities related to this milestone include the Preliminary Information Survey and the Definition of the Requirements Program and Terms of Reference (TR), which, once validated by the client, lead to the definition of the information requirements for the retrofit. This latter activity results in the development of the Field Survey Plan, based on the analysis requirements provided in a report by the Technical Consultant (Project Analyst).

The process continues to the client's validation of the Field Survey Plan only after confirmation from the Technical Consultant (Project Analyst) that all necessary requirements for the building analysis have been addressed.

The outputs of this project phase include: the Diagnosis, Feasibility Study, and Preliminary Inventory of the target building, the Requirements Program for the retrofit, the Terms of Reference (TR), and the Field Survey Plan.


INFORMATION REFERENCE
Interview report with client and users
Documentation/ Models of the target building and related materials
Site visit report (in-person/remote)
Related technical and scientific publications
Construction documents/models
Historical modification report
Program of Requirements/ Terms of Reference
Analysis Requirements Report
PROCESS
START
Planning
Preliminary Information Survey
Project Coordinator/ BIM Author
Planning
Definition of Program of Requirements and Project Terms of Reference
BIM Author
NO (Review and Update)
YES
Validated by the Client?
Planning
Definition of Information Requirements for Retrofit
BIM Author
NO (Review and Update)
NO (Review and Update)
Does it meet the performance analysis requirements?
YES
Validated by the Client?
YES
DELIVERY MILESTONE 01
OUTPUT DATA
Diagnosis / Feasibility Study / Inventory
Program of Requirements
Project Terms of Reference
Analysis Report
Client Approval Statement
Field Survey Plan
Analysis Report
Client Approval Statement

Delivery Milestone 2

Upon validation of the Field Survey Plan by the client, the Survey phase begins, involving activities such as data acquisition based on the Survey Plan and the pre-processing of the collected data. If these data meet the requirements for project analysis, they support the development of BIM Templates and Libraries. It is important to note that new surveys may be requested—or previously conducted ones repeated—if deemed necessary by the Technical Consultant (Project Analyst).

Once the Templates and Libraries are validated by the coordination team, the workflow proceeds to the development of the As Is models. It is worth noting that the development of the information models is directly influenced by the BIM Coordination activities within the Coordination and Verification flow, guided by the Verification and Compatibility Reports. As soon as the As Is model meets all information requirements, its sharing is authorized. From that point on, the Compatibility Assessment is carried out by the BIM Coordination team.

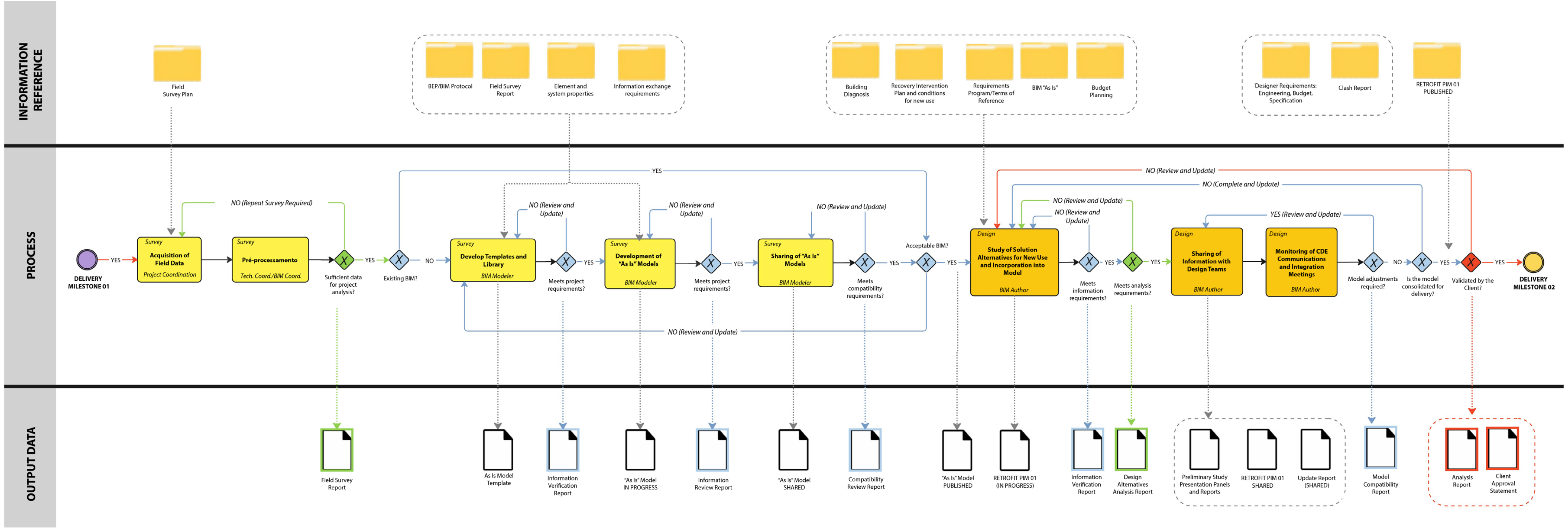
Only after the model is deemed suitable for use (Acceptable) by the BIM Coordination is its appropriation authorized for the development of design studies for the new use. During the Survey phase, the deliverables include: the As Is Information Model Template, the in-progress As Is Model (for internal use by the task team), the shared model (accessible for consultation by other task teams), and the published model (accessible to project teams and the client).

In the Design Concept phase, the solution study for the new use is developed, following the same workflow previously established with the BIM Coordination team during the As Is Model development. At this stage, it is essential to highlight the requirement for solution analysis by the Technical Consultant (Building Analyst). Only if the model meets the key analysis requirements is it authorized for sharing with other project teams. Upon sharing, a new compatibility assessment is carried out. Once the model is finalized and validated by BIM Coordination, it proceeds to Client Review and Approval.

The deliverables for this stage include the PIM 01

Information Model (in-progress, shared, and published), as well as presentation boards and written reports of the preliminary study.

As in previous stages, it is critical that the BIM project development schedule account for the information maturation process within the models. This is essential because, should inconsistencies be identified in relation to the established requirements—whether by the BIM Coordination or the Client—the information production cycle for these models may restart with each verification round.



Delivery Milestone 3

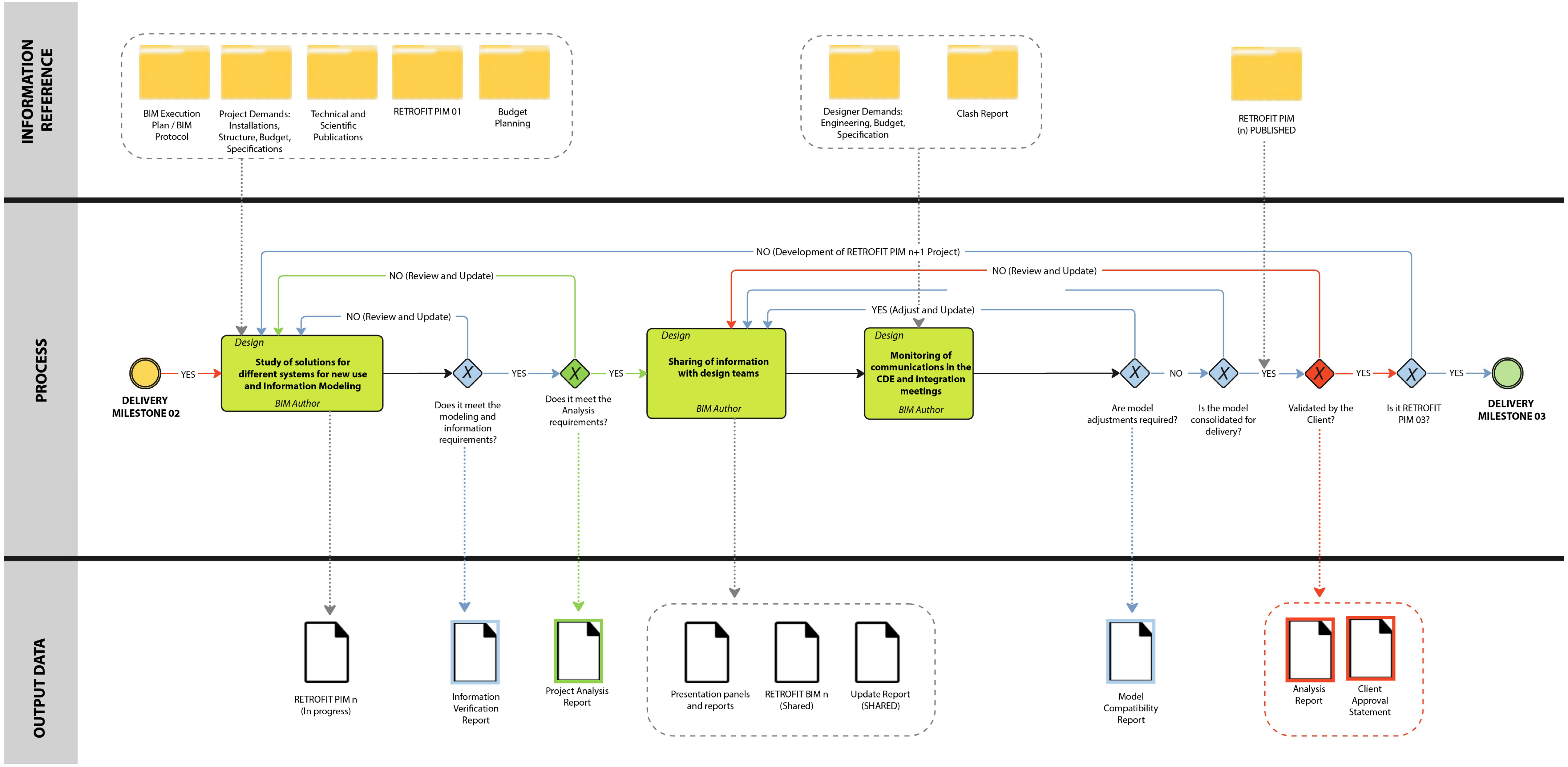
In the Design phase, studies are developed concerning the solutions for the various systems related to the new use of the building, as well as the corresponding information modeling. These follow the same BIM workflow established during the development of the PIM 01 Project Information Model in coordination with the BIM team. This phase also highlights the requirement for Solution Analysis by the Technical Consultant (Building Analyst). The model is only authorized for sharing with other project teams if it meets the key analysis requirements. From that point onward, the Compatibility Assessment is conducted.

Once the model is consolidated and validated by the BIM Coordination team, it proceeds to Client Review and Approval, in accordance with the delivery milestones defined for each development phase of the project.

This delivery milestone is only considered complete once the Detailed Design Information Model (PIM 03) is finalized and approved by the client. If the model is still at the Schematic Design stage (PIM 02), the workflow restarts with the development of the corresponding solution for the next design phase (Detailed Design).

The deliverables for this project phase include the RETROFIT PIMn Information Model (in progress, shared, and published), as well as the presentation boards and reports related to both the Schematic Design (PIM 02) and the Detailed Design (PIM 03.

As in previous phases, it is essential that the BIM project development schedule incorporates the information maturation process within the models. This is necessary because, if inconsistencies are identified in relation to the established requirements—by either the BIM Coordination or the Client—the information production cycle may restart with each verification iteration.



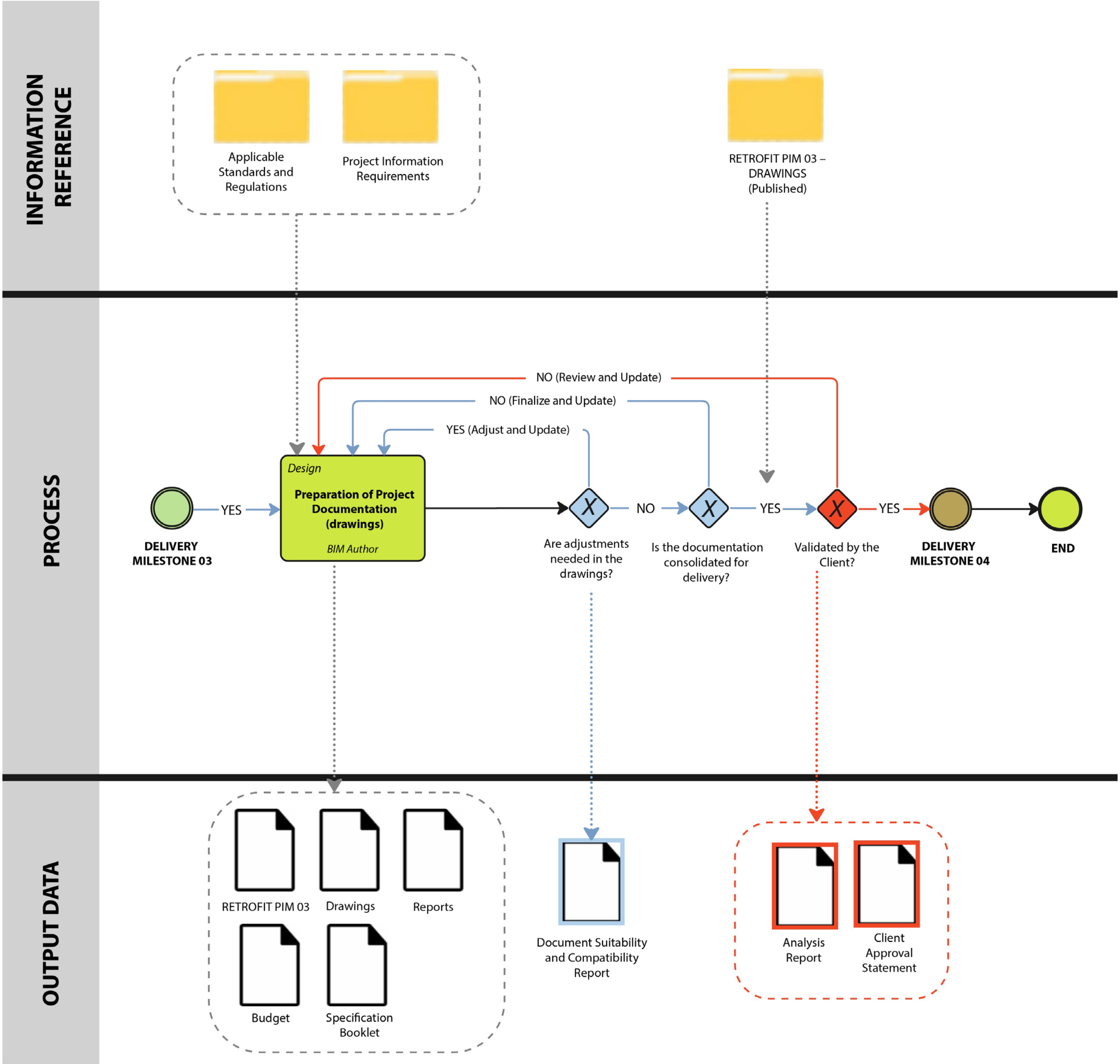
INFORMATION REFERENCE
PROCESS
OUTPUT DATA
BIM Execution Plan / BIM Protocol
Project Demands: Installations, Structure, Budget, Specifications
Technical and Scientific Publications
RETROFIT PIM 01
Budget Planning
Designer Demands: Engineering, Budget, Specification
Clash Report
RETROFIT PIM (n) PUBLISHED
NO (Development of RETROFIT PIM n+1 Project)
NO (Review and Update)
NO (Review and Update)
NO (Review and Update)
YES (Adjust and Update)
DELIVERY MILESTONE 02
YES
Design
Study of solutions for different systems for new use and Information Modeling
BIM Author
Does it meet the modeling and information requirements?
YES
Does it meet the Analysis requirements?
YES
Design
Sharing of information with design teams
BIM Author
Design
Monitoring of communications in the CDE and integration meetings
BIM Author
Are model adjustments required?
NO
Is the model consolidated for delivery?
YES
Validated by the Client?
YES
Is it RETROFIT PIM 03?
YES
DELIVERY MILESTONE 03
RETROFIT PIM n (In progress)
Information Verification Report
Project Analysis Report
Presentation panels and reports
RETROFIT BIM n (Shared)
Update Report (SHARED)
Model Compatibility Report
Analysis Report
Client Approval Statement

Delivery Milestone 4

In order to optimize the modeling process, the production of technical project drawings only takes place after the validation of the Detailed Design (PIM 03), at the final stage of its development. Delivery Milestone 4 begins with the preparation of the documents that support the understanding and execution of the project, following the same workflow established with the BIM Coordination team. This workflow is defined during the development of the Project Information Model. Once the model is finalized and validated by BIM Coordination, it proceeds to Client Review and Approval.

The deliverables of this phase include the RETROFIT PIM 03 model, technical drawings, specification reports, the budget, and the specification booklet.

As with previous stages, it is essential that the BIM project development schedule accounts for the information maturation process within the documentation. This ensures that, should inconsistencies be identified in relation to the established requirements—by either BIM Coordination or the Client—the information cycle for these documents can be restarted with each verification round.


INFORMATION REFERENCE
Applicable Standards and Regulations
Project Information Requirements
RETROFIT PIM 03 – DRAWINGS (Published)
PROCESS
NO (Review and Update)
NO (Finalize and Update)
YES (Adjust and Update)
DELIVERY MILESTONE 03
YES
Design
Preparation of Project Documentation (drawings)
BIM Author
Are adjustments needed in the drawings?
NO
Is the documentation consolidated for delivery?
YES
Validated by the Client?
YES
DELIVERY MILESTONE 04
END
OUTPUT DATA
RETROFIT PIM 03
Drawings
Reports
Budget
Specification Booklet
Document Suitability and Compatibility Report
Analysis Report
Client Approval Statement

BUILDING ANALYSIS

This workflow encompasses all diagnostic activities that support project decision-making, including energy performance analysis, structural analysis, identification of pathologies, evaluation of existing systems, and so on.

Additionally, the definition of information requirements to be collected and produced to enable diagnostics, along with the assessment of the survey plan and scheduling of investigations and tests, are integral components of this phase.

Delivery Milestone 1

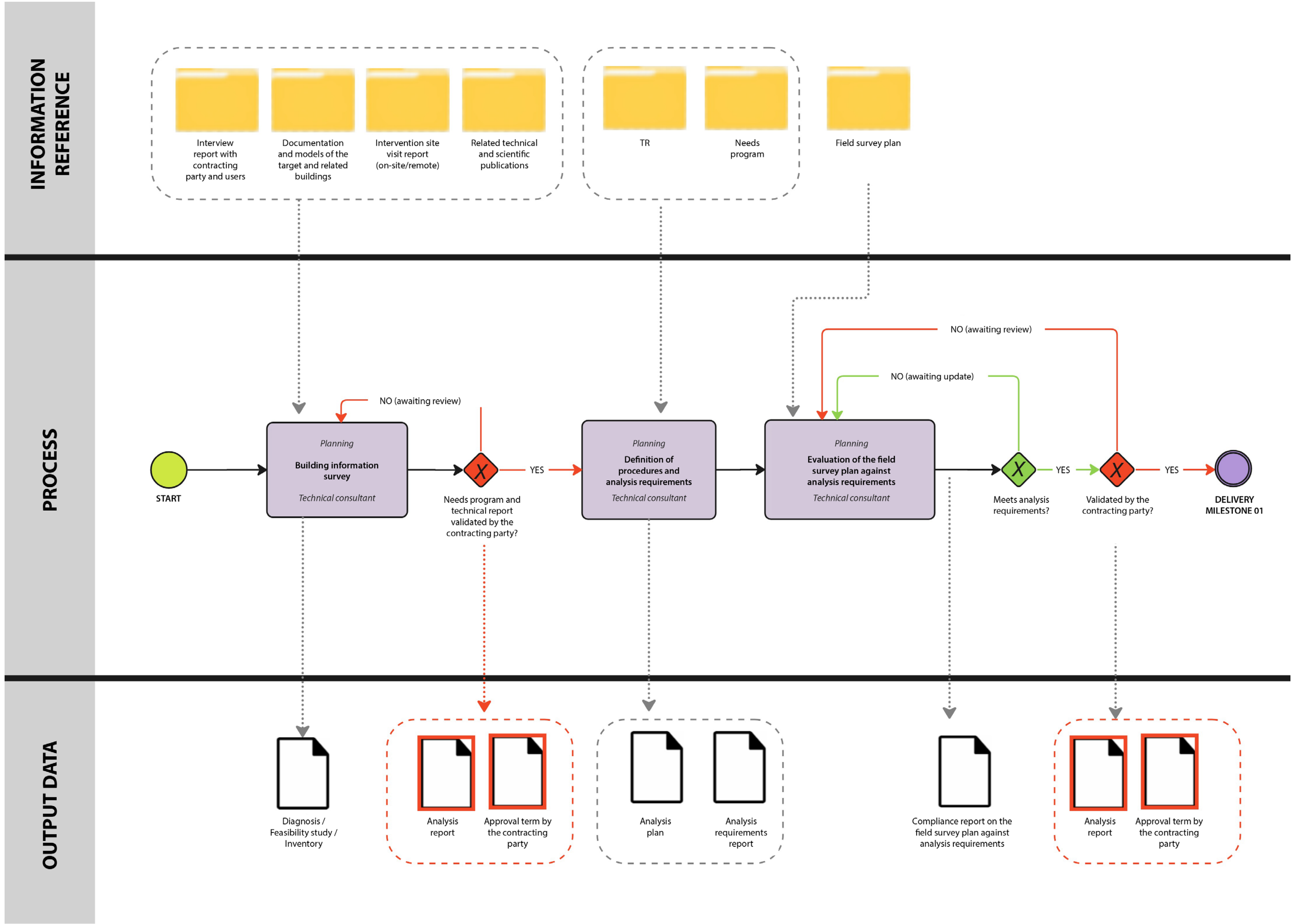
During the Planning phase, the Technical Consultant (Building Analyst), using the data available on the target building, guides the BIM Authors in developing the Preliminary Diagnosis, Feasibility Study, and Inventory, which form the basis for the elaboration of the Requirements Program and the Terms of Reference (TR).

Only after these documents are approved by the Client does the Definition of Analysis Procedures begin, based on the information provided in the TR and the Requirements Program. This process results in the Analysis Plan and the Analysis Requirements Report, which are intended to inform the Field Survey Plan developed by the BIM Authors.

Before being submitted to the Client, the Field Survey Plan must be reviewed and validated by the Technical Consultant (Building Analyst), who must issue a Conformance Report verifying whether the plan meets the analysis requirements.

The documents produced during this phase include the Analysis Plan, the Analysis Requirements Report, the Survey Plan Conformance Report, and the Analysis Requirements.

As with the previously described phases, it is essential to incorporate the information maturation process into the BIM project development schedule. This ensures that, in the event inconsistencies are identified by either the Building Analyst or the Client, the information production cycle for these deliverables can be restarted at each verification round.



Delivery Milestone 2

During the Survey phase, regarding the information requirements for conducting the analyses, the workflow begins with the evaluation of field data collected by the BIM Authors and documented in the Field Survey Report. The result of this evaluation is recorded in the Field Data Conformance Report, which aligns the data with the established Analysis Requirements. If any data do not meet the necessary criteria, a new field survey must be conducted.

Once the adequacy of the field data is confirmed, the analysis procedures begin. These include planning and documenting the processes in a specific protocol for each type of analysis, incorporating the information into the analysis tool, configuring parameters related to materials, systems, and uses, and performing a preliminary analysis to evaluate the tool's processing capabilities.

If the processing is deemed appropriate, the analysis is formally executed, resulting in the Building Diagnosis.

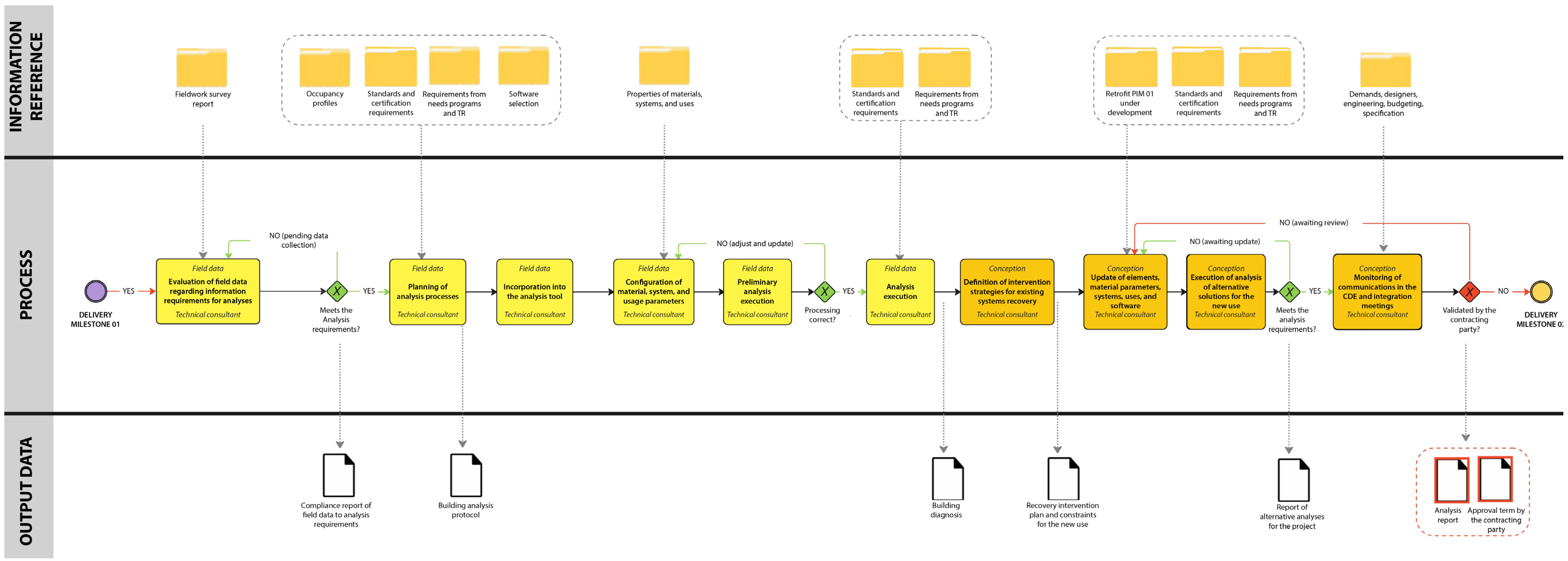
The Field Data Conformance Report, the Building Analysis Protocol, and the Building Diagnosis are the key deliverables of this stage.

Based on the diagnosis, in the Design Concept phase, recovery interventions for the existing systems are defined. These lead to the development of the Recovery Intervention Plan and the conditions for the new use, which guide the BIM Authors in defining solution alternatives as the building's functions are updated. Once the BIM Authors consolidate these alternatives, they must be submitted to the Building Analyst for verification of compliance with the analysis requirements. Subsequently, the elements and parameters are updated, followed by the execution of the analysis of the proposed alternatives.

Before these solution alternatives can be shared with other teams, they must be evaluated and validated by the Technical Consultant (Building Analyst), who issues an analysis report confirming, or not, the adequacy of the proposed solution.

The model workflow then follows the processes described in the Development of Project/Asset Information Models and the Information Model Coordination flow, and it must be monitored by the Building Analyst to support the BIM Authors' decision-making. This milestone concludes with the validation of the PIM 01 (Preliminary Study) Information Model by the Client.

The Recovery Intervention Plan, the Conditions for the New Use, and the Project Alternatives Analysis Report are the primary deliverables of this phase.



Delivery Milestone 3

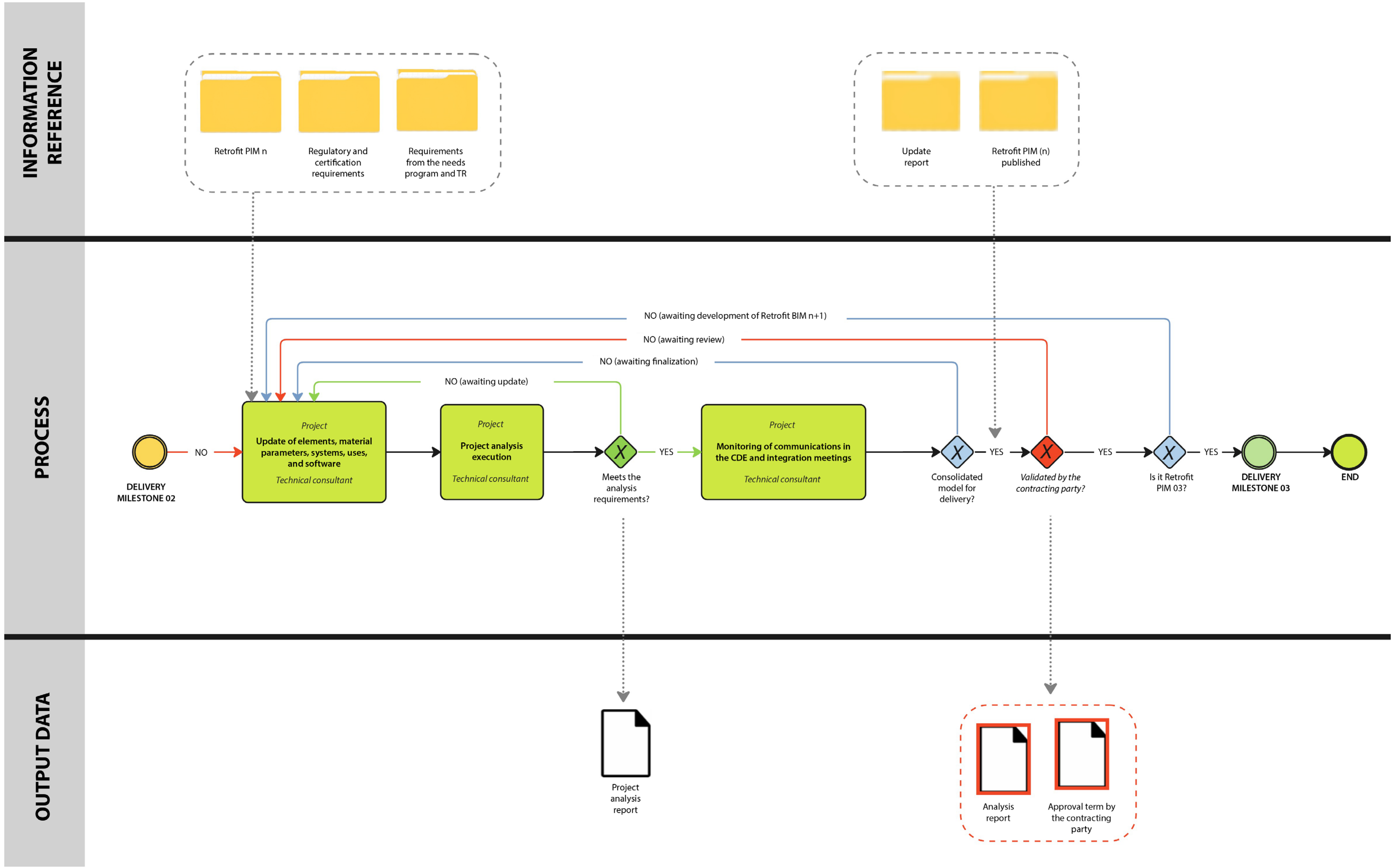
This milestone begins during the Design phase, in which updates are made to elements, material parameters, systems, usage definitions, software tools, and the execution of the project analysis itself.

Before being shared with other teams, the RETROFIT PIM(n) Project Information Model must be evaluated and validated by the Technical Consultant (Building Analyst), who issues an analysis report confirming, or not, the adequacy of the Project.

The model workflow proceeds in accordance with what is outlined in the Development of Project/ Asset Information Models flow and the Information Model Coordination flow. It must be monitored by the Building Analyst to guide the decision-making process of the BIM Authors. Once the model is finalized and validated by BIM Coordination, it proceeds to Client Review and Approval.

This delivery milestone is only considered complete once the Executive Design Information Model (PIM 03) is finalized and validated by the client. If the model still corresponds to the Schematic Design stage (PIM 02), the workflow restarts, pending the development of the solution for the next design phase (Executive).

The Project Analysis Reports for the RETROFIT PIM 02 (Schematic Design) and RETROFIT PIM 03 (Executive Design) models are the key deliverables of this stage.



INFORMATION REFERENCE
PROCESS
OUTPUT DATA
Retrofit PIM n
Regulatory and certification requirements
Requirements from the needs program and TR
Update report
Retrofit PIM (n) published
NO (awaiting development of Retrofit BIM n+1)
NO (awaiting review)
NO (awaiting finalization)
NO (awaiting update)
DELIVERY MILESTONE 02
NO
Project
Update of elements, material parameters, systems, uses, and software
Technical consultant
Project
Project analysis execution
Technical consultant
Meets the analysis requirements?
YES
Project
Monitoring of communications in the CDE and integration meetings
Technical consultant
Consolidated model for delivery?
YES
Validated by the contracting party?
YES
Is it Retrofit PIM 03?
YES
DELIVERY MILESTONE 03
END
Project analysis report
Analysis report
Approval term by the contracting party

DELIVERABLES ANALYSIS

This process encompasses the Planning, Survey, Design Concept, and Design phases. All information produced must be validated by the client at specific delivery milestones. The Deliverables Analyst's workflow includes team training and the analysis and validation of all Published deliverables.

Client analysis and validation constitute a prerequisite for the project to proceed. This ensures a closer alignment between the deliverables expected by the client and those produced by the project teams. However, it is understood that all previously described workflows are contingent upon feedback from the analyst in order to advance to the subsequent activity. As such, this task requires a high level of responsibility and commitment from the client, since delays in this analysis may impact the overall project timeline.

Delivery Milestone 1

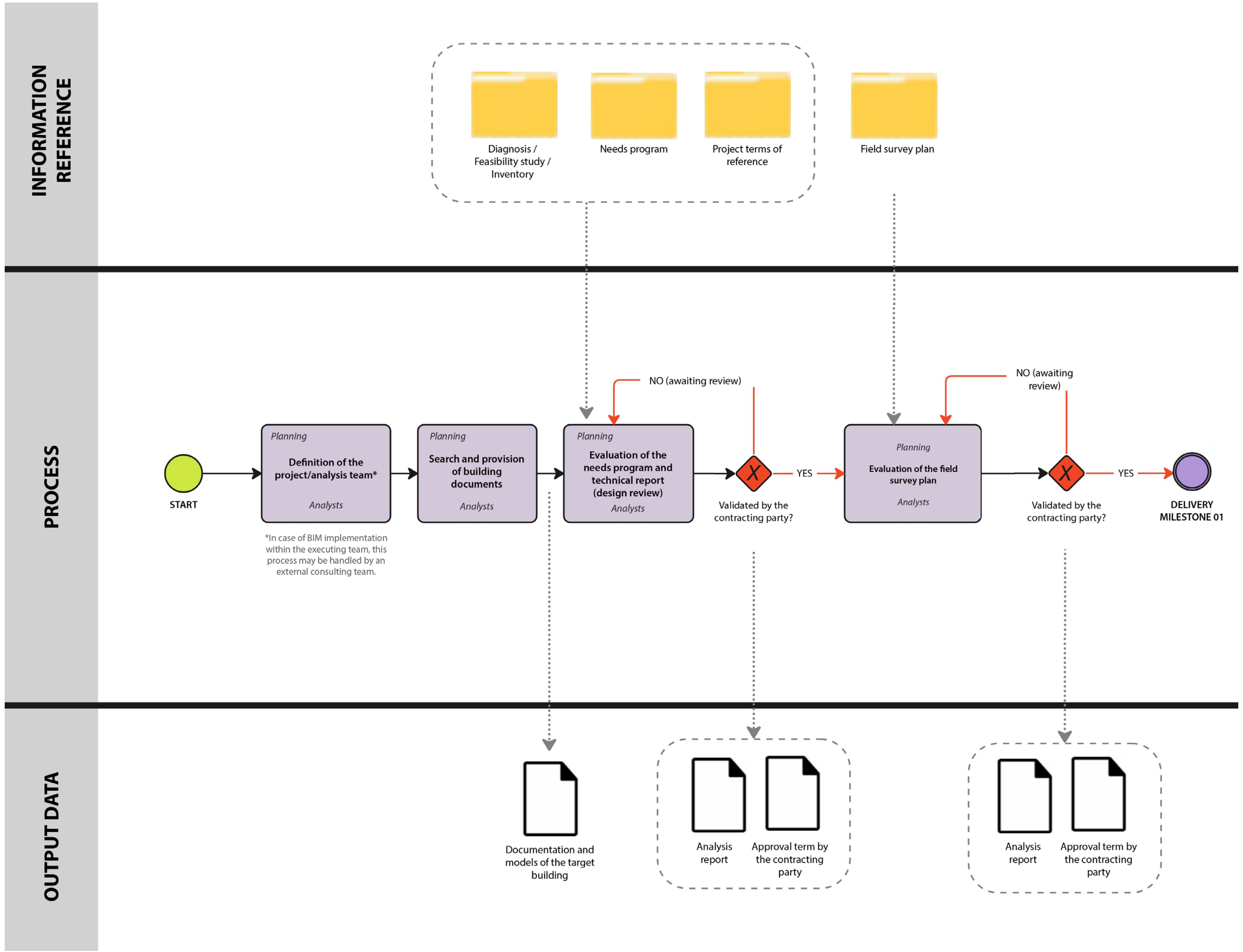
This milestone begins in the Planning phase, during which the analysis team is defined. If the client's internal execution team is still in the process of implementing BIM, this task may be delegated to an external team.

The appointed team begins by gathering and providing the relevant documents and models of the target building to the contracted project teams. This enables them to initiate their workflows, culminating in the preparation of the Preliminary Diagnosis, Feasibility Study, and Inventory, followed by the Requirements Program and Project Terms of Reference (TR). Once made available by the contracted party, these deliverables are reviewed and validated by the Deliverables Analysts to ensure compliance with the Contract Requirements and the specific demands of the project. In case of non-compliance, the products must be revised and republished for further evaluation.

The building documents and models, the Analysis Report, and the Client Approval Statement are generated at this stage.

Once these products are approved by the Deliverables Analysts, the process awaits the publication of the Field Survey Plan. At that point, the Analyst is activated to evaluate and validate the plan in accordance with the Contract Requirements and the specific project demands—particularly with regard to budgeting. If any non-conformities are identified, the plan must be revised and republished for reevaluation. This milestone concludes with the approval of the plan by the Analysts.

The Analysis Report and the Client Approval Statement are the deliverables associated with this activity.



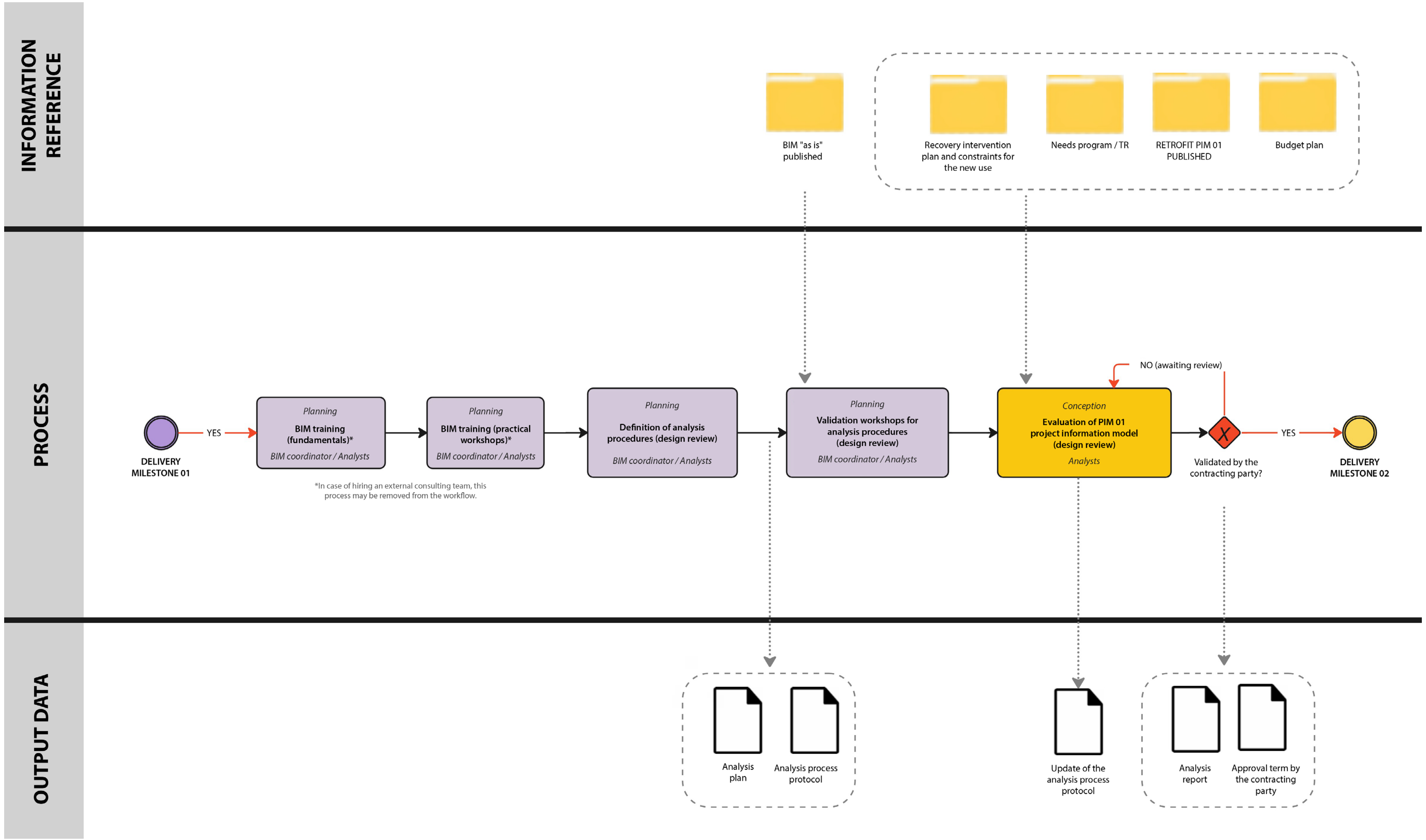
Delivery Milestone 2

This milestone begins during the Planning phase, with the training of analysts in BIM fundamentals and the execution of Practical Workshops. It is worth noting that, in the case of hiring an external consulting team, this training step may be omitted from the workflow. After this activity, the Analysis Procedures are defined collaboratively by the Analysts and the BIM Coordination team. This process concludes with a Workshop to validate the procedures, using the BIM As Is Asset Information Model as a reference.

The Analysis Plan and the Analysis Procedures Protocol are the deliverables generated from these activities.

From this point forward, the Design Concept phase begins, during which the analysts initiate the evaluation of the Project Information Models based on the procedures defined and validated during the planning phase. At this stage, the model under review is the study model known as RETROFIT PIM 01, which is used to support the development of the Recovery Intervention Plan and the conditions for the new use, the Requirements Program, the Terms of Reference (TR), the Budget Plan, and the specific project demands. If the model does not comply with the established requirements, it must be revised and republished before a new evaluation can be performed. This milestone concludes with the Approval of the RETROFIT PIM 01 Project Information Model by the Analysts.

The Update of the Analysis Protocol and Process based on insights gained, the Analysis Report, and the Client Approval Statement are the key deliverables associated with this milestone.



INFORMATION REFERENCE
PROCESS
OUTPUT DATA
BIM "as is" published
Recovery intervention plan and constraints for the new use
Needs program / TR
RETROFIT PIM 01 PUBLISHED
Budget plan
DELIVERY MILESTONE 01
YES
Planning
BIM training (fundamentals)*
BIM coordinator / Analysts
Planning
BIM training (practical workshops)*
BIM coordinator / Analysts
Planning
Definition of analysis procedures (design review)
BIM coordinator / Analysts
Planning
Validation workshops for analysis procedures (design review)
BIM coordinator / Analysts
Conception
Evaluation of PIM 01 project information model (design review)
Analysts
NO (awaiting review)
Validated by the contracting party?
YES
DELIVERY MILESTONE 02
*In case of hiring an external consulting team, this process may be removed from the workflow.
Analysis plan
Analysis process protocol
Update of the analysis process protocol
Analysis report
Approval term by the contracting party

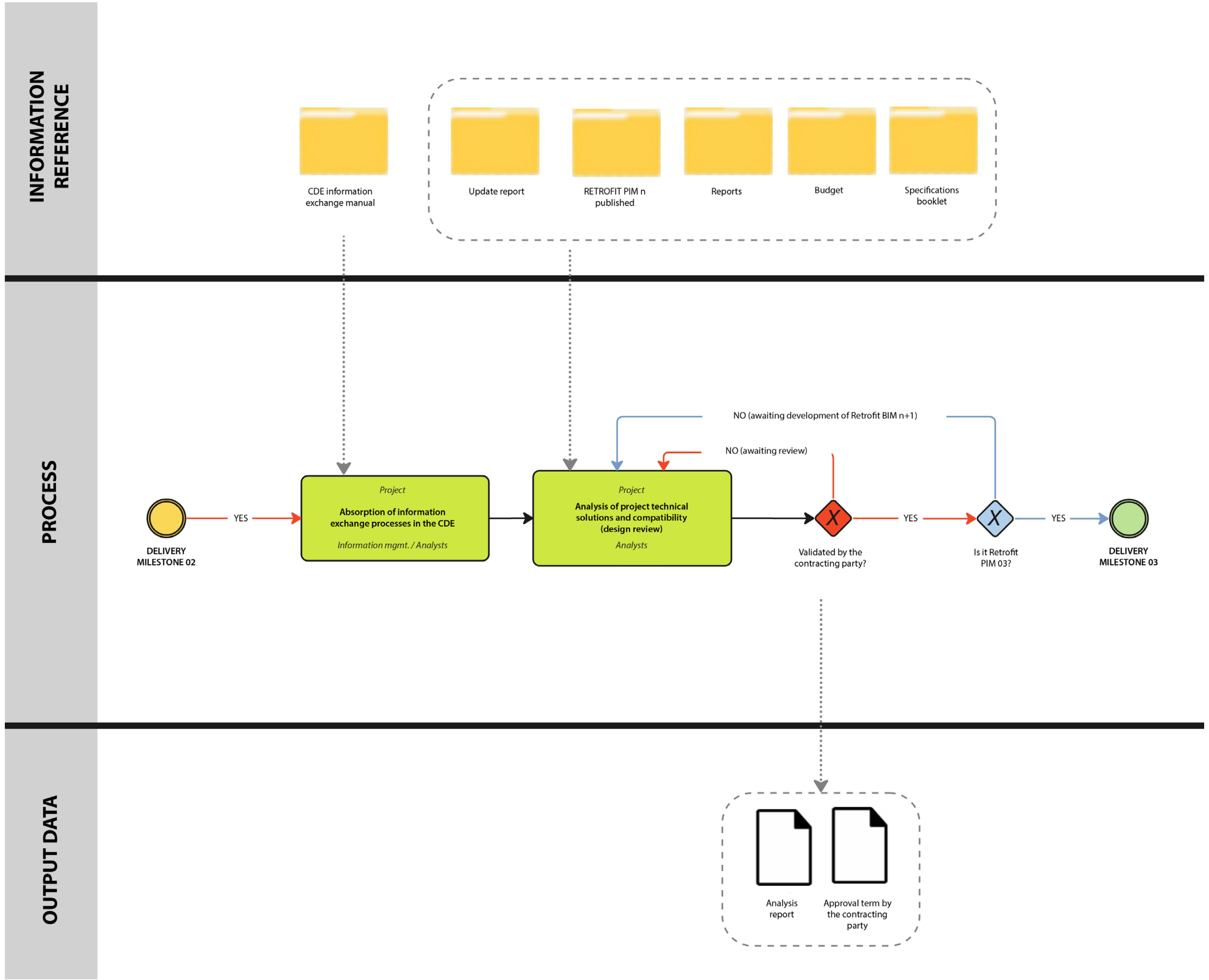
Delivery Milestone 3

During the Design phase, while the BIM Authors are developing the Schematic Design, the analysts begin assimilating the information exchange processes within the Common Data Environment (CDE), using as reference the CDE Information Exchange Manual prepared by the BIM Coordination team and updated in accordance with the lessons learned throughout the project development.

Once the CDE processes have been assimilated, the analysts begin the Evaluation of the Project Information Models. At this stage, the models under evaluation are the Schematic Design models known as RETROFIT PIM 02, which inform the preparation of the Update Report (in relation to the previously reviewed model), as well as the Specification Reports, Specification Booklets, and the Budget, in addition to addressing the specific requirements of the project.

If the model does not meet the necessary requirements, it must be revised and republished before a new evaluation can take place. This milestone concludes with the Publication and Approval of the Executive Design Information Model RETROFIT PIM 03 by the Analysts.

The Analysis Reports and the Client Approval Statements are the deliverables generated in this phase.



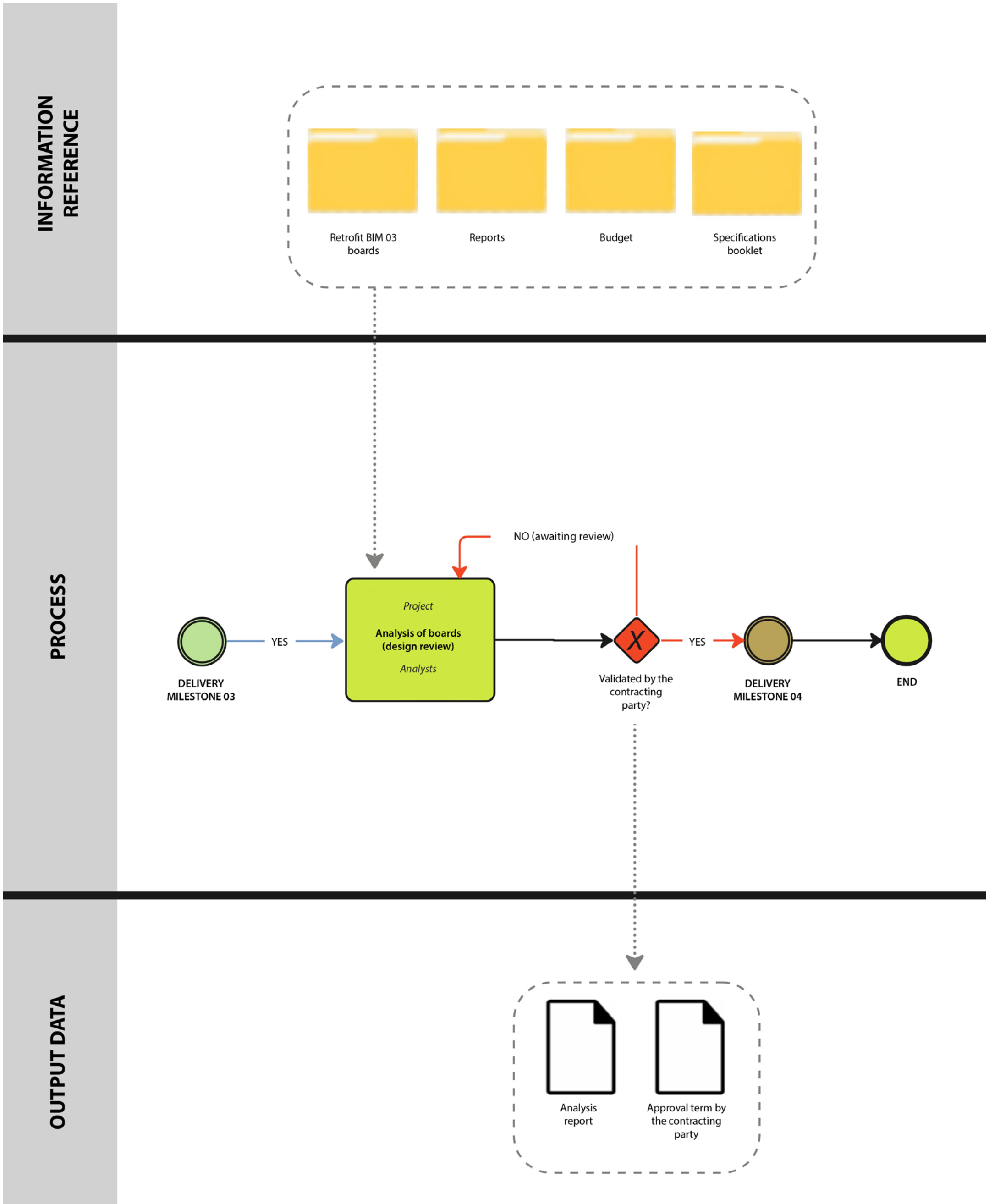
INFORMATION REFERENCE
PROCESS
OUTPUT DATA
CDE information exchange manual
Update report
RETROFIT PIM n published
Reports
Budget
Specifications booklet
NO (awaiting development of Retrofit BIM n+1)
NO (awaiting review)
DELIVERY MILESTONE 02
YES
Project
Absorption of information exchange processes in the CDE
Information mgmt. / Analysts
Project
Analysis of project technical solutions and compatibility (design review)
Analysts
Validated by the contracting party?
YES
Is it Retrofit PIM 03?
YES
DELIVERY MILESTONE 03
Analysis report
Approval term by the contracting party

Delivery Milestone 4

Delivery Milestone 4 begins with the analysis of the documents that support the understanding and execution of the project. This analysis includes reviewing the drawings of the Project Information Model RETROFIT PIM 03, the technical reports, the specification booklets, and the budget, as well as ensuring alignment with the specific requirements of the project.

In case of non-compliance, the drawings and other documents must be revised and republished for further evaluation. This milestone concludes with the approval of the documentation related to the RETROFIT PIM 03 executive design by the Analysts.

The Analysis Reports and the Client Approval Statements are the deliverables of this phase.


INFORMATION REFERENCE
PROCESS
OUTPUT DATA
Retrofit BIM 03 boards
Reports
Budget
Specifications booklet
NO (awaiting review)
DELIVERY MILESTONE 03
YES
Project
Analysis of boards (design review)
Analysts
Validated by the contracting party?
YES
DELIVERY MILESTONE 04
END
Analysis report
Approval term by the contracting party

FINAL CONSIDERATIONS

At the conclusion of the consolidation of this Manual, it is possible to observe the fulfillment of the research's primary objective: to investigate the mechanisms for developing the BIM methodology in retrofit proposals. This work aims to offer methodological contributions that enable the dissemination of BIM practices within the Federal District.

To validate the methodological artifact, it was applied in a pilot project. Based on this application, analyses, evaluations, and adjustments were made to the processes and procedures through workshops involving industry stakeholders.

This research consolidates the artifact using a dialogical language that is accessible and easily applicable by construction sector professionals involved in the process, thereby reducing project execution time and promoting the implementation of BIM tools and methodology in retrofit projects.

Nonetheless, some challenges remain to be addressed, such as the development of Cost Estimation Workflows, the Construction Phase, Asset Operation and Maintenance, and the Demolition Process. Therefore, further research will be necessary in order to fully address the entire Building Lifecycle.

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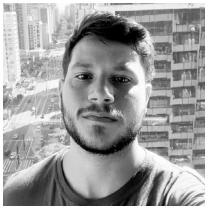

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