ANALYSIS AND IMPLEMENTATION OF BUILDING MAINTENANCE PLANS BASED ON BUILDING INFORMATION MODELS (BIM) APPLIED IN MEXICO

POLITECNICO MILANO 1863

SCHOOL OF ARCHITECTURE, URBAN PLANNING AND CONSTRUCTION ENGINEERING (AUIC)

MASTER OF SCIENCE IN BUILDING AND ARCHITECTURAL ENGINEERING

Master Dissertation of:

Omar Perez Carbajal – 904241

Supervisor: Prof. Bruno Daniotti

Co-supervisor: Eng. Gustavo Amosso

Academic Year 2018/2019

Abstract

L'obiettivo di questo studio è analizzare l'implementazione di piani di manutenzione strutturata supportati da un Building Information Model (BIM), considerando le diverse sfide che questa iniziativa potrebbe comportare in Messico, e sulla base della standardizzazione disponibile svolgere un piano di base applicato in una costruzione reale. Pertanto, lo studio sarà sviluppato in una sequenza di fasi in cui verranno spiegate le principali definizioni e requisiti.

In primo luogo, verrà discussa la situazione nazionale relativa alla manutenzione delle construzioni e le sfide che devono affrontare durante il loro ciclo di vita tra le fasi operative e di ristrutturazione, indicando i punti di miglioramento e le possibili soluzioni.

In secondo luogo, sarà studiato verso la standardizzazione internazionale il processo richiesto per stabilire un piano operativo BIM attraverso la categorizzazione dello stato di ciascun elemento costruttivo e stabilendo un criterio standardizzato che possa essere utilizzato con il supporto degli strumenti BIM.

In terzo luogo, una volta definito il contesto nazionale e lo scopo da analizzare, verrà proposto un piano di gestione delle informazioni basato sullo standard nazionale recentemente pubblicato relativo agli strumenti BIM per qualsiasi scopo costruttivo (NMX-C-527-1-ONNCCE-2017), verificando la compatibilità e rafforzando le prescrizioni attuali con il mainframe di standardizzazione internazionale disponibile a diversi livelli, in modo che il processo possa essere più affidabile.

In quarto luogo, il processo proposto sarà testato su un caso di studio locale, basato su una scuola di medie dimensioni nel periodo medio del suo ciclo di vita, concentrandosi sugli impatti che il tempo e l'ambiente hanno causato allo stato originale, organizzando le informazioni dell'edificio sin dalla sua fase di progettazione, definendo i guasti e proponendo un piano di manutenzione basato sulle soluzioni che possono essere adottate per avere la costruzione in condizioni ottimali fino alla fine del suo ciclo di vita.

Infine, saranno fornite conclusioni che mettono a confronto l'implementazione dei piani di manutenzione BIM con il processo tradizionale eseguito in Messico, indicando i benefici e i miglioramenti futuri non solo negli edifici di piccole e medie dimensioni, ma anche nell'industria edilizia nazionale.

Abstract

The objective of this study is to analyse the implementation of structured maintenance plans supported by a Building Information Model (BIM), considering the different challenges that this initiative may imply in Mexico, and based on the standardization available purpose a base plan applied in a real construction. Thereby, the study will be developed in a sequence of steps where the main definitions and requirements will be explained.

Firstly, will be discussed the national situation related to asset maintenance and the challenges that constructions endure during its lifecycle span between operation and refurbishment stages, pointing the improvement points and possible solutions.

Secondly, will be studied towards the international standardization the process required to establish a BIM operative plan by the categorization of the state of each constructive element and establishing a standardized criterion that can be used with the support of the BIM tools.

Thirdly, once defined the national context and the scope to analyse, it will be proposed an information management plan based on the recently published national standard related to BIM tools for any construction purpose (NMX-C-527-1-ONNCCE-2017), checking compatibility and reinforcing the current prescriptions with the international standardization mainframe available at different levels, so the process can be more reliable.

Fourthly, the proposed process will be tested on a local study case, based in a medium size school at the medium span of its life cycle, focusing on the impacts that the time and the environment had caused to the original state, organizing the building information since its design stage, defining the failures and proposing a maintenance plan based on the solutions that can be adopted to have the construction in optimal conditions until its lifecycle end.

Finally, conclusions will be given comparing the implementation of BIM maintenance plans against the traditional process executed in Mexico, pointing the benefits and future improvements not only in small and medium size buildings, but also in the national building industry.

Useful Terms and Abbreviations.

ACI	American Concrete Institute
AIM	Asset Information Model
AISC	American Institute of Steel Construction
AIR	Asset Information Requirements
ASTM	American Society for Testing and Materials
BEP	BIM Execution Plan
BIM	Building Information Model
BPIM	Building Process and Information Management
BSI	British Standards Institution
CDE	Common Data Environment
CEEH	Centro Educativo Estado de Hidalgo (Study case)
COBie	Construction Operations Building Information Exchange
EIR	Exchange Information Requirements
IDM	Information Delivery Manual
IFC	Industry Foundation Classes
IMP	Information Management Plan
ISO	International Organization for Standardization
MVD	Model View Definition
OIR	Organizational Information Requirements
ONNCCE	Organismo Nacional De Normalización y Certificación de la Construcción y Edificación
PAS	Publicly Available Specification
PIM	Project Information Model
SAMP	Strategic Asset Management Plan

Contents

1. Introduction

Constructions have faced during centuries a fight against the decay process caused by different factors including its surrounding context, accidents, or the daily operation. Thus, this situation derived in the implementation of activities that could make a construction and its components to be more durable and functional along the time. Nowadays, this set of activities are part of the maintenance concept essential to keep an asset in optimal condition during its lifecycle.

In addition, the information process of constructions has evolved with the technology development, departing from the first attempts of a project portfolio (including plans and site records), to then have more complex information systems having interaction between the different project specialties using common tools based on software. In the current construction industry, information management plans are a powerful solution to have reliable data of each stage of the construction project, permitting the users to have enough resources to perform their tasks and share the information with all the entities involved in the project.

One of the most developed tools to comply with the information sharing process and allow the control of the building during its different stages is the Building Information Model (BIM), where is possible to centralize all the information fluxes happening during the entire lifecycle of the construction in one digital model. Thereby, every event happening in the analysed project can be recorded and have a strong information basis where better decision can be taken.

These two concepts (maintenance and BIM information plans) can be useful to solve some ingrained problems happening in the building context of Mexico, a country where the construction standardization is being developed towards the creation of specialized standards in which the rules of project information sharing are set based on the use of BIM.

One of these problems is related to a lack of an organized process where the maintenance activities could be organized and executed following a proper information record. Usually, building maintenance is done once the symptoms of total failure of the constructive component are manifested, having unplanned and expensive solutions, as well as possible affectations on other components due to bad planning of works.

At international level, countries are managing to solve similar issues by means of a preventive culture, which includes periodic inspections and the implementation of scheduled maintenance activities. Thereby, owners and maintenance performers can manage better the resources needed to keep the building in good conditions and at the same time reduce the possibility to have serious unexpected failures that require immediate attention.

Thus, the objective of this paper is to set the context in which a building maintenance plan can be organized and developed to reduce the decay process in small and medium size buildings in Mexico, analyzing the context and information available and later on, setting the basis where a structured plan based on BIM can be used to enhance the organization of maintenance activities, allowing the implementation of a preventive culture in the national infrastructure.

2. State of Art

2.1. Construction and Maintenance in Mexico.

"Maintenance: combination of all technical and associated administrative actions during the service life to retain a building, or its parts, in a state in which it can perform its required functions"

Source: ISO 15686-1:2011

The concept and study of procurement and maintenance in medium and small size constructions in Mexico is relatively new, mainly because it is not yet established a preventive culture in which building components are periodically inspected and have a documentation process. As a result of this situation, in many cases maintenance works happen when a certain construction or its components develop a total failure, and there is no other alternative than replace the entire layer.

This problematic always derives in higher operation costs for the owners, as it is proven that component total replacing activities requires more economy and time resources, rather than perform controlled inspections and take actions at the first manifestation of failure.

In order to understand the main causes of the maintenance issues in Mexico, there will be studied 2 main factors, the first one related to the technological solutions used in the major part of the constructions and secondly, the information available about the products life cycle and the possible actions to keep every building component in a state that still can develop its functions until the end of its operative life.

2.1.1.Technological solutions.

Based on the fact of being in a mild climate condition and having moderate material resources in a good part of the country, the constructive systems adopted in Mexico at residential/commercial level consist in simple solutions, taking advantage of the local materials availability and construction procedures applied generation by generation.

Figures 2.1 & 2.2. Examples of wet construction concrete systems. (Source: CEEH photographic register)


Figures 2.3 & 2.4. Examples of local brick wall systems. (Source: CEEH photographic register)

Normally these solutions rely on masonry walls (block or brick) and wet construction systems (poured concrete slabs), leaving the pre-fabricated materials mainly for bigger projects or specific uses, this is due to the higher cost sometimes or even the lack of knowledge on how to apply these solutions.

Moreover, construction processes are still based in the workforce quality and a proper field monitoring, leaving mechanized work solutions only for the projects that can afford it. Therefore, the time lapse for a construction from the constructive phase to the operative one is susceptible to a lot of changes. At the same time, this situation can cause a different performance in the technological solutions applied, as if not followed the needed time to cure the components, issues can happen since the beginning of the asset life cycle, compromising the future stages.

If analyzed the possible damage of the mentioned technologies due to the daily use of the asset, it can be settled that in the chosen group of buildings the factors that really can affect progressively the state of the construction are minimum, as the constructive systems applied are meant to be resistant if a good execution during its erection is guaranteed, allowing the building to be in an optimal state for a long period of its life cycle.

Nevertheless, the lack of a preventive culture can accelerate the deterioration of the systems, as commonly, this kind of buildings are subject of unregistered modifications or failures derived to malfunctioning of additional subsystems of the asset such as hydraulics, plumbing or air conditioning. If these situations are left unattended, the minimum affectations derived by the controlled use of the building can be exponentially increased and have a quicker decay of the technology components, deriving in local layer failures or even worse a total failure of the total component of the building system.

In addition, the environment plays an important role to define the actions to be performed, as in such a big country as Mexico, the variety of climatic and social contexts is extremely variated, giving different decay situations even having optimal work execution and using the same technologies and materials between buildings. Consequently, is needed a standardized procedure that can allow the design and procurement teams to take better decisions to have suitable solutions according with the mentioned context, helping to reduce the operation costs and unnecessary refurbishments due to bad material choices.

2.1.2. Constructive process and Materials standardization.

As commented in previous lines, the resource availability in a good part of the country allows the constructors to trust in local manufacturers to supply the materials in field. Consequently, materials can vary according with the supply quality and the fabrication process in each place, having results that can overpass or be under the project expectations and requirements.

Moreover, this situation can derive in future problems on the execution of the project or even failures due to the quality of the material, that in most of the cases, are compensated with empirical methods in field, which are not always registered causing misunderstandings between the execution and the maintenance stages.

Particularly, this is visible in the basic construction supplies, such as masonry units, concrete aggregates and earthwork materials, where everything is ruled by the local use of the materials and the way to work them. Therefore, the project and the execution sometimes are adapted to the supplies, contrary on what is expected in a traditional construction.

If the supply and its fabrication/extraction procedure is considered optimal by the local construction performance, local suppliers can rise to a higher level, giving service at regional or even at national level. In addition, architects and builders based on other construction experiences usually trust in this regional success cases, not always following a good scientific performance but a simple good appearance or workability of the supply.

Figure 2.5 Examples of local supply processes. (Source: Local factories)

On the other hand, if referred to materials and systems where is required a precise methodology and controlled supplies, the quality and durability of the construction may become unpredictable, as the empirical procedures and knowledge used in an important amount of constructions along the country gets confronted with the standardized way of work, not always having the best results.

In order to solve this situation, builders tended to trust in international standards and products, despite of the costs, to ensure the quality that the project required. These products, due to the vicinity of Mexico with the United States, were based in the American Society of Testing Materials (ASTM) standards, as they are frequently used as reference in Latin America, and because of the lack of national standardization that could regulate these procedures at a regional level.

Since 1994, and seeing the need to implement a reliable standardization process that could impulse the building industry in Mexico, was created the ONNCE (National Normalization, Construction and Building Certification Organism in English) to establish the basic standardization frame in which the constructive processes could follow organized processes in which could be guaranteed a quality standard, improving the service life of the assets and trying to fill the information voids generated between the construction and operation stages of the building.

Thanks to these efforts, supply providers with help of the big construction and services companies are migrating to the standardized process suggested by the created norms, as it has proven with the time and implementation that the standardization had not the purpose of eradicate the traditional construction processes followed until now, but to improve and bring them the merited validity towards a procedure in which the good things can be replicated and applied in different projects and circumstances.

Furthermore, having a standardization base, the industry is also implementing the declarations of performance of specific products and procedures, giving reliability for the construction specialists at the time of choosing between different solutions, and having more information to take better decisions.

Once these efforts become a more solid reality into the industry, it will be possible to make another big progress like to implement the Life Cycle Assessment methodology to know the real impact of a constructive system in all its stages. For this step is needed to work with industrials and manufacturers about the environmental performance and how to declare it. In this way, it is not just improved the performance of the building industry, but at the same time, could be possible to make it more efficient using less resources and avoiding as possible the environmental impact caused by the construction industry in its different stages.

2.1.3. Reference standards in Mexican industry.

Once establishing the national realities in terms of construction and standardization in small and medium buildings, in this section will be treated the appliance of internal standards property of parastatal commissions in Mexico, which are commonly used in absence of a specific standardization for certain construction procedures.

This is because during the second half of the 20th century, parastatal institutions with the objective to set the rules and requirements to develop primary infrastructure works, elaborated internal procedures based on industrial standards of the American standardization (ACI, AISC, ASTM), which are always the nearest reference to be used due to vicinity of the countries,

Thanks to the implementation of these procedures and the stable economic situation In the country, it was possible to impulse infrastructure projects along all the national territory, mainly based in petrol extraction, refineries and electricity generation plants and its distribution mains, giving value to the country development objectives and giving to the commissions in charge the strength not only to promote the industrial progress, but at the same time, providing information and training to their employees, having a more prepared workforce able to face the challenges demanded by the industrial growth forecasted by the government.

Observing the good results of these internal procedures in the infrastructure built, different construction companies started to implement their structure in all the projects by means of contracting former personnel from the national parastatals which had the technical expertise to bring these results to common use buildings allowing a better quality in the construction, and therefore, a higher durability and less costly in its operation.

One of these success cases, are the standards developed by the Federal Commission of Electricity (CFE), specifically the Test, Equipments and Materials Laboratory (LAPEM), in which, regardless the main scope are electricity and distribution projects, there were developed various processes regarding the construction and maintenance of this kind of infrastructure, to be followed by the personnel in charge during all the stages of the asset lifecycle.

As an example, the Civil Works Design Manual (Manual de Diseño de Obras Civiles in Spanish) is a common reference when needed to ensure a more detailed design referring to the structural loads and material requirements for more complex buildings, as the technical data used in their considerations studies all the national territory, as well as is constantly updated giving the designer the reliable criterion required.

Regarding constructions and their components, LAPEM standardization sets minimum material quality for specific processes referred to specific standard (ASTM or ONNCCE), as well as suggested procedures including drawings and criterion to develop the different works related to the primary infrastructure projects execution and handover.

In terms of maintenance, these standards proposed a structured methodology in which can be identified every item under study and its belonging specialty, as well as a set of rules regarding process organization and work safety to follow under the development of these activities. With this, all the parts involved know their responsibilities and can execute every task with a documented registration and an approval process by the supervisor in charge.

Having this in mind, is possible to take advantage of these organized structure followed in primary infrastructure, to set the basis for a standardization of the construction procedures in common use buildings, spreading these good results in form of agreed standards and procedures to follow in building of different sizes and complexities.

Taking a simple example, in the following figure is shown a suggested object maintenance format, with the information process starting since the total identification of the object, the next step is to describe the possible anomalies found during a physical inspection, to then give an evaluation and perform corrective actions. This process finishes with the specialty supervisor approval and information archive.

REV: 0
Hoja 1 de 1

ASSET COMPLEX NAME

OBJECT ID — TAG DEL EQUIPO: ________ *BUILDING* — EDIFICIO: ________ *LEVEL* — NIVEL: ________

DESCRIPCIÓN DEL EQUIPO: ________
OBJECT DESCRIPTION

FECHA: ________ *DATE* TURNO: ________ *TURN* *SPECIALTIES INVOLVED* MEC ☐ ELECT. ☐ I & C ☐

ANOMALY DESCRIPTION
DESCRIPCIÓN ANOMALÍA: ________

NOMBRE DEL ORIGINADOR: *DEVELOPER NAME* ________

EVALUATION AND WORK DONE
EVALUACIÓN/TRABAJO EJECUTADO: ________

NOMBRE DEL TÉCNICO: *EXECUTOR NAME* ________

OBSERVACIONES: *OBSERVATIONS* ________

ANOMALY FIX VERIFICATION ANOMALÍA CORREGIDA: SI ____ NO ____

REPORTS ELABORATED AFTER WORK SE ELABORÓ SM No. ________

SE GENERÓ REPORTE DE CONDICIÓN RC No. ________

FIRMA J.T./I.T./SUPERV. REMI

____
SUPERVISOR NAME

Sólo para Información

Figure 2.6 Standard maintenance work format (Source: CFE internal procedure)

As can be seen in the format, its design allows the user to input the required information on an easy way, as there are well defined sections in which each process is registered. In addition, a document codification is proposed to organize the processes in different dates and specialties, being part of a bigger information system shared with all parties involved.

This kind of formats are especially useful to introduce the documentation process on each stage subject to analysis in the building, and having these basic formats set, is easier to develop more specific or complex formats requiring other kind of information.

Despite the fact that these procedures sometimes are internal and confidential, can be developed with the help of the industry free use formats or procedures to register every task performed in different situations, as will be seen in later chapters, some industrial process can become available for public use with the support of national standardization organisms as ONNCCE.

In this way, can be complied the objective pursued in this study, to bring the tools in which the building process can be better registered and the good things done until now can be even better guaranteeing reliable infrastructure easy to operate and durable for all the desired purposes.

2.2. Information Management Process & BIM Methodology and uses.

Constructions (whether commercial or industrial) have been always one of the most important development factors that a country can have throughout its history, as they represent the technological progress and the workforce quality available. These factors are in constant evolution with the aim to have every time even better infrastructure and more durable along its lifetime cycle.

This constant improvement needs to be enriched with effective working strategies in all the productive stages of the asset, which can enhance the coordination between the different specialties involved and generate information tools towards a standardized procedure, so every part of the design, construction and maintenance stages is able to take better decisions with the correct set of documents.

Nowadays, in a building industry that demands every time quicker processes and better quality, national and international standardization organizations developed standards to set the rules in which coordination between the asset phases and the different specialties can happen. BSI PAS 1192-2 standard proposes the collaborative working strategy with the following definition:

"In a collaborative working environment, teams are asked to produce information using standardized processes and agreed standards and methods, to ensure the same form and quality, enabling information to be used and reused without change or interpretation"

This definition is crucial if it is analyzed the working process in the bigger construction companies, where optimal information exchange channels are needed to coordinate multi-disciplinary projects in different locations and progress stages.

If referred to the European and North American context, there is a good development of the information management process standardization, making it available for different kinds of projects, and even making innovative initiatives, such as data bases about constructive products and procedures available for public use and digital systems to manage the information of the construction at every stage of its life cycle.

In contrast, looking at smaller scale companies and projects, it is possible to find a very wide range of procedures, everyone with its own rate of success and fail, sometimes due to a lack of knowledge of the standardization available or even the absence of this.

Besides, in the case of developing countries, is possible to find a totally different reality, in which the information exchange channels are still reserved only for the most developed construction companies by means of their internal procedures if available. In addition, is quite common to face the lack of a clear standardization regarding this topic as it is not yet studied and considered as a matter of real importance.

This situation is leading the need of initiatives to enhance the building information management process which can be reliable and applicable for local and international companies and with different complexity projects.

As a result of this need, the construction industry is moving to rely in digital tools to enhance the coordination of the different areas and stages of the project. Therefore, Building Information Models (BIM) are becoming one of the most powerful tools to use as base frame for the collaborative working strategy. With the purpose of giving a basic definition, ISO TS 12911:2012 standard explain the process with the following statement:

"*Building Information Modelling (BIM)*: *use of a shared digital representation of a built object (including buildings, bridges, roads, process plants, etc.) to facilitate design, construction and operation processes to form a reliable basis for decisions"*

If it is analysed the definition provided, becomes relevant the term "reliable basis for decisions", as if the building information modelling is done in a structured and collaborative way, all the relevant processes related to the construction or any asset in question, can be developed in a more efficient way as it is counted with the correct and precise information. In addition, ISO 19650-1 standard states the following benefits of using BIM:

"These processes can deliver beneficial business outcomes to asset owners/operators, clients, their supply chains and those involved in project funding including increase of opportunity, reduction of risk and reduction of cost through the production and use of asset and project information models."

Implementing a Building Information Model requires a change in the way to think the project design process, passing from the traditional way (2D plans, specifications, and schedules) to have a digital model where all these processes can interact, becoming a strong information system able to phase the challenges of every stage of the asset.

Therefore, ISO 19650-1 standard exemplifies the different progressive stages of the asset that could be covered with the information management process during the asset life cycle, such as:

- Strategic planning
- Initial design
- Engineering
- Development
- Documentation and construction
- Day-to-day operation
- Maintenance
- Refurbishment
- Repair
- End-of-life

Besides of the benefits and stages mentioned, it is important to introduce the life cycle definition. This term is a key point to understand the purpose and at which level is desired to develop the information process and the resources that this task may have. The standard defines it as:

"Stages and activities spanning the life of the system from the definition of its requirements to the termination of its use, covering its conception, development, operation, maintenance support and disposal"

In further chapters, will be explained the importance of defining in which stage of the asset lifecycle is applied the information management process, as the information resources will need to be managed accordingly with the phase desired.

Nevertheless, even considering that the concepts and methodologies mentioned above can be standardized and followed by different countries, there are still specific needs that every place needs to cover according with its coordination and technological level. Consequently, international and local standardization shall provide the necessary framework to cover this wide variety of situations.

Following the idea of defining the specific needs of in each country, it will be analysed the specific case of Mexico, where, as developing country, the success or failure of a constructive projects relies more on a good construction execution and empirical solutions rather than on a standardized procedure, having a wide gamma of results. Consequently, the concept of building information management can be useful not to replace the current procedures, but to improve them and make the infrastructure quality even better in different complexity levels.

Consequently, with the aim to provide a guideline to this study, is proposed to focus in the operative stage of the constructions, where is seen a great opportunity area to improve the processes, considering the possibility to implement maintenance plans using the building information management process.

For this, is important to form an information basis with all the information available of the existing construction object of this study, such as project plans, photographic records, calculations and documents related to any modification made in the constructive elements along its operative life. To comply with this task, coordination and communication with the owner and project architect will be essential to get the most reliable documentation, and set the needed starting point where the information management process will be developed and illustrate its results in the BIM.

As well, and part of the information gathering process, a physical inspection to the asset will be done to know the current state of the construction, cross-checking the data retrieved from the documentation process against the inspection results, making a more realistic status of the asset and from it start to organize the different activities needed to develop the maintenance plan.

2.3. Interoperability and Industry Foundation Classes (IFC).

"Interoperability: Capacity offered to users of a software to share data with other software tools via a common standard data exchange method."

Source: Autodesk.com glossary

Continuing to follow the collaborative working principles, is important to set the bases in which all the specialties involved in a certain project can interact and exchange information on an efficient way so every crew has the most recent information and can work without delays or mistakes due to the lack of data coordination.

Consequently, the industry has developed powerful software tools that can make every specialty work much quicker and have more accurate results with the use of technology, allowing the construction projects to be executed and controlled since different perspectives at every time of its life cycle.

In contrast, it represents an enormous challenge to coordinate the information generated by the different specialties involved in the project, as each one may work with a different software and the inner structure of each program is not compatible with the others. This can derive in a project interoperability issue, as the collaboration between teams can be compromised due to a lack of communication between tools.

Furthermore, using Building Information Models (BIM) for design and management of the different building components, is needed to allow the exchange of big amounts of data, as in this way of work every component is input as an information container which has its own identity and different information parameters that define its characteristics.

Therefore, it was needed to create a common language between design and construction software tools, so the information generated in one specialty could work as a base point for the other ones, and each task team could work simultaneously in its field without interfering with the general progress of the design and execution project.

As a result, since 1994 buildingSMART organization (formerly Industry Alliance for Interoperability) developed a global standard used to share and manage information between platforms. This standard evolved in what is known nowadays as Industry Foundation Classes (IFC). The following definition is proposed by the buildingSMART organization:

"IFC is a standardized, digital description of the built asset industry. It is an open, international standard (ISO 16739-1:2018) and promotes vendor-neutral, or agnostic, and usable capabilities across a wide range of hardware devices, software platforms, and interfaces for many different use cases."

In addition, buildingSMART explains that IFC works as a data model in which the different types of information that could be input in each software are codified in a logical way by means of a unified information schema. Some examples of information inputs are:

- I**dentity** and **semantics** (*name, machine-readable unique identifier, object type or function*)
- **Characteristics** or **attributes** (*such as material, color, and thermal properties*)
- **Relationships** (including locations, connections, and ownership)
- **Objects** (like columns or slabs)
- **Abstract concepts** (performance, costing)
- **Processes** (installation, operations)
- **People** (owners, designers, contractors, suppliers, etc.)

Source: buildingSMART.org

This standardization effort is extremely important in the current building industry, as the migration from traditional information processes to Building Information Models (BIM) is a reality in many activities supporting the construction field, such as engineering, construction products development and manufacturing. In addition, thanks to its benefits in the interoperability is becoming a requirement for public works in many countries around the world, allowing a more effective information management during all the stages of the building lifecycle.

Despite of the advantages of this information exchange resource, interoperability is not completely achieved only by means of the IFC creation. As can be expected, during the information generation process done by each specialty can be input a huge amount of data, which is not precisely needed for all the involved teams. For this reason, inside the IFC schema is possible to create data subsets available for a certain use or workflow. According with the definitions provided by buildingSMART organization this is called Model View Definition (MVD).

With the creation of different MVD's, is possible for the BIM responsible to manage the amount and level of detail of the information to be delivered to the different specialties, as each one will have its own data needs. In this way, every task team can work inside its proper MVD without affecting other information processes inside the IFC.

To define the scope of each MVD, is necessary to define the different requirements and information transactions that a certain process inside the IFC will have in accordance with the project guidelines. For this, the international standardization introduces the creation of an Information Delivery Manual (IDM) with the following definition:

"IDM: documentation which captures the business process and gives detailed specifications of the information that a user fulfilling a particular role would need to provide at a particular point within a project."

Source: ISO 29481-1:2017

In the same way, the standard establishes the minimum content that must have every IDM to define the sub-process for which is needed to generate information, so and IDM shall:

- Describe the need for information exchange within the business context.
- Identify the actors sending and receiving information.
- Define, specify and describe the information being exchanged to satisfy the requirements at each point within the business context.
- Ensure that definitions, specifications, and descriptions are provided in a form that is useful and easily understood.
- Create detailed specifications of the information captured within exchange requirements to facilitate the development of BIM software applications.
- Ensure that the information specifications can be made relevant to local working practices.

In consequence, a MVD is a “Taylor made” suit that covers the specific content conditions of a specific specialty IDM (MEP, structural analysis, costs, etc.), or can happen that a well-planned MVD could cover the needs of a group of IDM’s having similar requirements. As well, there are some standardization established MVD’s that can suit a specific task inside the IFC and have a validity not only in the internal process of a building, but also work as reference in a company or even as a national standard.

If speaking about maintenance and asset life cycle studies, one of the most common MVD’s is the Construction Operations Building Information Exchange (COBie), in which is provided as-built data of a determined asset for the owner reference or operations related to the facility management. COBie can be represented in different ways according with the project needs, the most well-known is in form of a spreadsheet with a specific structure and format in which the output information is classified, while the amount and information needs of it will depend on each project and the level of detail that is expected.

All these definitions and resources helped to make the interoperability a reality in which the construction industry can rely on, allowing different task teams to interact in a common language, and sharing vital project information for all the specialties involved, making sure that every party will have its needed information resources and respect the outputs desired and settled in the IDM’s developed by the BIM management.

Nevertheless, thinking in this IFC approach to enhance the interoperability between project instances can develop a very problematic challenge if the rules of operation of this data are not set since the earlier stages of the project. Firstly, is needed to name an administration entity which will oversee the information exchanges management and to dose the data required in the model for each specialty involved in the project. As well, this entity will not only deal with the operative part of the project but also to be the representative of the information management process with the owners and higher level interested parties.

Secondly, even in big companies where IFC files and infrastructure is firmly established, is common to find mistakes during the information transfer between one software and other. Despite the fact of sharing the same language provided by the IFC data, this happens because every program has its own way to code the output files, and in this different data treatment, some information might be lost in the transfer from one process to other. With the time, some of these issues are solved by the respective software support and international standards, but is important every time to verify the

IFC accuracy and once done, deliver it to the needed processes and avoid a mistake replication in all the tasks involved in the project.

Thirdly, this approach can derive in disagreements between specialties, as maybe the program or way of work of one task team may not be compatible with the digital information exchange proposed by the collaborative work approach or does not have the ability to accept IFC import and export. If is desired a complete interoperability between project specialties using IFC, there must be an agreement about the software to be used between all the task teams, ensuring that the IFC approach can be followed and the information exchange can be done offering different software solutions so the task team can choose the most appropriate and allow the information flow needed in the project development.

This issue can happen mainly in countries where the BIM approach and interoperability methodology are very recent or the tools available may not are enough to have a complete interaction by means of IFC between all the specialties. This is the case of Mexico, where is recently developed the very first BIM standardization approach as an initiative to start working using this kind of methodology to improve the industrial processes related to construction. As well, there is not created a unified way of collaborate between different specialties, which makes that every team to have its own internal procedures and deliver some information that might not be structured in a proper way, causing misunderstanding and information loses during all the stages of the project.

To make this methodology work, is not needed only the knowledge of the interoperability concepts by one user or company, but also an industrial effort that enhances the use of these tools and show the benefits of the collaborative working in projects of different sizes and complexities. As can be expected, analyzing the experience of countries where this approach is a reality, the results of these efforts might not be immediate, as to change the perspective of a complete industry sector implies time and resources to test and implement this method adapted to the national situation.

Furthermore, is needed the support of a national initiative that makes the interoperability a regulated process and an accepted format for infrastructure projects in the public sector as happen in United Kingdom, where now is a requirement and allows the government take better decisions based on the information provided every time by the IFC's delivered by the contractors during the asset construction.

In this way, when the government instances are able to promote the interoperability as a development objective for the industry, and having companies that can implement IFC approach in different scale projects, will be possible to have a proper information exchange environment, where processes and techniques can be shared and improved using information tools, allowing the industry to take the next step and implement strategies where not only the design or operation of an asset are included in this information strategy, but also construction service providers and product manufacturing companies can be part of this shared environment and help rising a building industry that requires improved processes and more efficient ways of working.

2.4. Standardization Analysis.

"An information management process is started each time a new delivery phase or operational phase appointment is made, irrespective of whether this appointment is formal or informal. This process involves preparation of information requirements, review of prospective appointed parties in relation to information management, initial and detailed planning for how and when information will be delivered, and review of information deliverables against the information requirements before they are integrated with operational systems. The information management process should be applied in a way that is proportionate to the scale and complexity of the project or asset management activities."

(Source: ISO 19650-1:2018)

As the information management process can have different approaches and perspectives based on the needs and the situation of each country, in this chapter will be introduced the key processes and definitions inside an information management plan. In addition, will be analyzed the specialized standardization in 3 different levels, focusing on their similarities and defining the procedure to be followed, following 3 different levels as explained in figure 2.7.

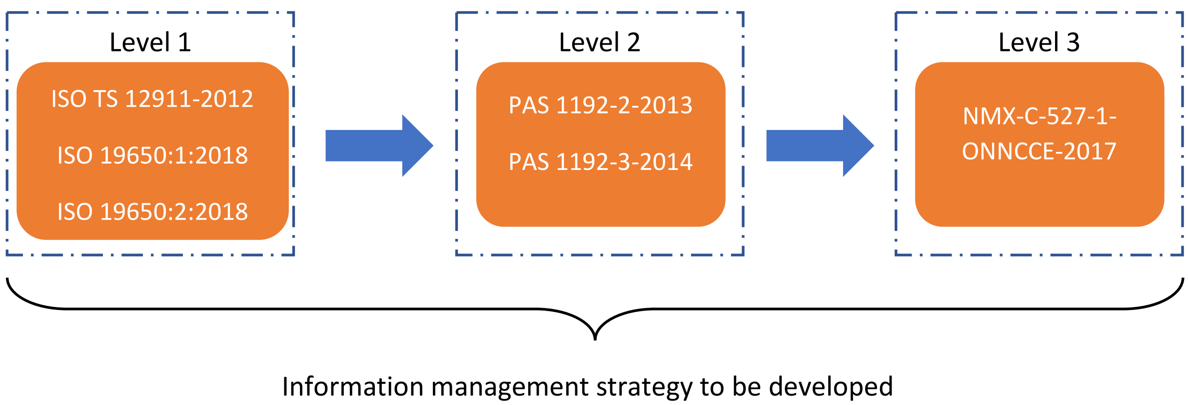


Figure 2.7 Standardization analysis flow

Firstly, at an international level, was analyzed inside the International Organization for Standardization (ISO) family, the standardization available in terms of information management for different type of assets and the mainframe involving these activities, considering that these norms at international level can be used to bring support to any national regulation available and give it more strength and validity.

Secondly, were taken as reference the Publicly Available Specifications (PAS) developed with collaboration of the British Standard Institution (BSI), in which is provided guidance for the information management requirements associated with projects using Building Information Modelling (BIM). These guidelines became relevant at the point that are at the same time adopted as a common practice procedure in countries member of the European Union.

Thirdly, from the national point of view, will be discussed the most recent regulation related to information management in Mexico, developed by the ONNCCE (Organismo Nacional de Normalización y Certificación de la Construcción y Edificación S.C.).

In this norm, were discussed the main definitions and activities to be developed inside the national context, and then, with the support of the two standardization levels previously discussed, it can be set a guideline in which the information management strategies can become a solid process to be followed in the Mexican industry, and to be adopted in different scale projects.

As a starting point, is needed to define the type of information pretended to be shared and its requirements. This is with the objective to define the level of detail that the information management process is targeted to achieve, and setting the tasks to perform in order to set the information exchange basis, analysing the information that could be gathered in each stage of the project according with the activities developed.

To understand and set the purposes of this process, ISO 19650-1:2018 standard recommends focussing the information management on the different perspectives related to the parties involved in the process. Knowing that every project will have its perspectives, in the following table are described the basis in which can be settled the analysis.

Table 1 — Information management perspectives

Perspective	Purpose	Example deliverables
Asset owner's perspective	To establish and maintain the purpose of the asset or project. To make the strategic business decisions.	Business plan Strategic asset portfolio review Life cycle cost analysis
Asset user's perspective	To identify the true requirements of the user and make sure the asset solution has the right qualities and capacities.	Project brief AIM PIM Product documentation
Project delivery or asset management perspective	To plan and organize the work, mobilize the right resources, coordinate and control development.	Plans, for example BIM Execution Plans Organizational charts Function definitions
Society's perspective	To make sure the community's interest is taken care of during the asset life cycle (planning, delivery and operation).	Political decisions Area plans Building permits, concessions
NOTE The example deliverables are relevant to the point of view of each perspective and do not indicate ownership of the deliverables or who does the work to produce the deliverables.		

Figure 2.8 (Source: ISO 19650-1:2018)

For this purpose, level 1 & 2 standard levels share the principle of a continuous workflow between the different information generators/providers and the receiving part. All these information exchanges must be ruled by a set of requirements that cover the project needs and the intended use of the information. All the parties involved in the generation/exchange of information must set their own information requirements to build an agreed plan in which everyone can work. BSI PAS 1192-2-2013 sets the following features:

"Information requirements shall be specific, measurable, achievable, realistic and time-bound against, for defined project stages and information exchanges."

To support this idea, ISO standards propose a requirement cycle according with the main stages of the asset, and arriving to the required information models suitable for the stage intended to analyse:

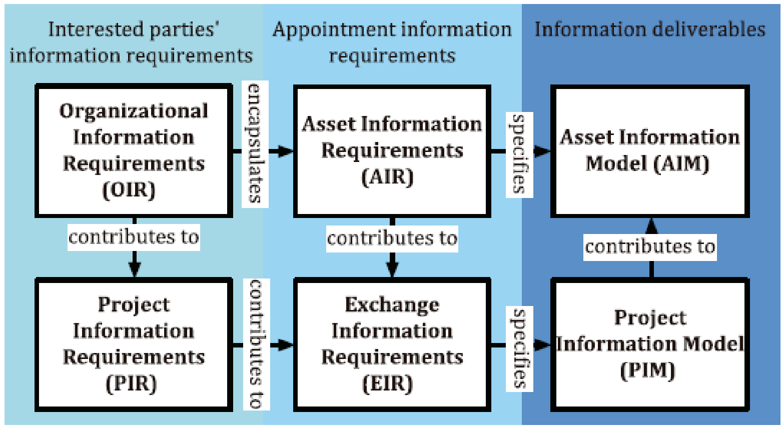


Figure 2.9 Information Requirements Cycle (Source: ISO 19650-1:2018)

By the purpose of this study, it will be studied the information model generation since the EIR stage, developing the Project and Asset Information Models with the objective to purpose an execution plan. Following ISO 19650-1:2018 are displayed the main definition of these stages:

Exchange information requirements (EIR)

EIR set out managerial, commercial, and technical aspects of producing project information. The managerial and commercial aspects should include the information standard and the production methods and procedures to be implemented by the delivery team.

The technical aspects of the EIR should specify those detailed pieces of information needed to answer the PIR. These requirements should be expressed in such a way that they can be incorporated into project-related appointments. EIR should normally align with trigger events representing the completion of some or all project stages.

EIR should be identified wherever appointments are being established. In particular, EIR received by a lead appointed party can be sub-divided and passed on in any of its own appointments, and so on along the supply chain. EIR received by appointed parties, including lead appointed parties, can be augmented with their own EIR. Some of the EIR can be passed to their own appointed parties, particularly where information exchange within a delivery team is necessary and this information is not to be exchanged with the appointing party.

Across a project there can exist several different appointments. The EIR from all these appointments should form a single coherent and coordinated set of information requirements, sufficient to address all the PIR.

To understand the respective information requirements, level 1 & 2 standardization levels divide the information management process in two main stages during the life cycle of the building, the first one related to the delivery phase of the asset, which includes all the design, construction and commission stages, and the second one related to the operation and maintenance of the asset. In the following figures can be appreciated the similarities between the international and British standards, as they are using the frame provided by the ISO 55000 standard.

Figure 2.10 ISO information approach (Source: ISO 19650-1:2018)

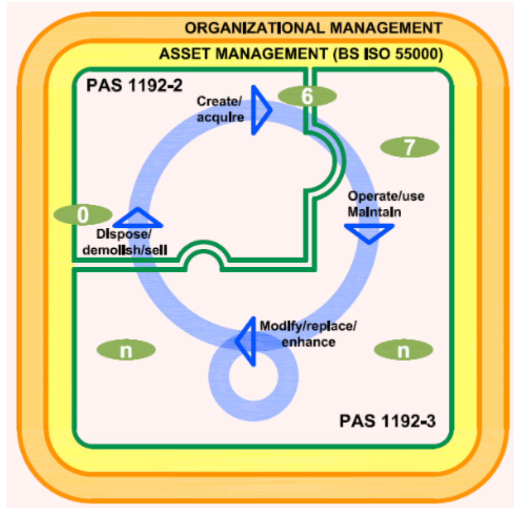


Figure 2.11 BSI information approach (Source: BSI PAS 1192-3-2014)

In addition, is possible to find in both regulations the equivalent information models according with its respective phase. Additionally, the definitions suggested by ISO 19650-1:2018 are provided.

Approach	Delivery phase model	Operative phase model
ISO	Project Information Model (PIM)	Asset Information Model (AIM)
BSI	CAPEX	OPEX

Figure 2.12 Model equivalence between standard levels.

Asset information model (AIM)

The AIM supports the strategic and day-to-day asset management processes established by the appointing party. It can also provide information at the start of the project delivery process. For example, the AIM can contain equipment registers, cumulative maintenance costs, records of installation and maintenance dates, property ownership details and other details that the appointing party regards as valuable and wishes to manage in a systematic way.

Project information model (PIM)

The PIM supports the delivery of the project and contributes to the AIM to support asset management activities. The PIM should also be stored to provide a long-term archive of the project and for auditing purposes. For example, the PIM can contain details of project geometry, location of equipment, performance requirements during project design, method of construction, scheduling, costing and details of installed systems, components and equipment, including maintenance requirements, during project construction.

In addition to the definitions explained before, it is important to establish that according with the development of each stage where information is exchanged, these models can get a maturity level which enables the parties involved to share information upon a detail level agreed during the EIR settlement. Therefore, current international standardization sets 3 different maturity levels based on the benefit development and the interoperability between users. In the next diagram is settled each maturity level towards different layers and its respective containers.

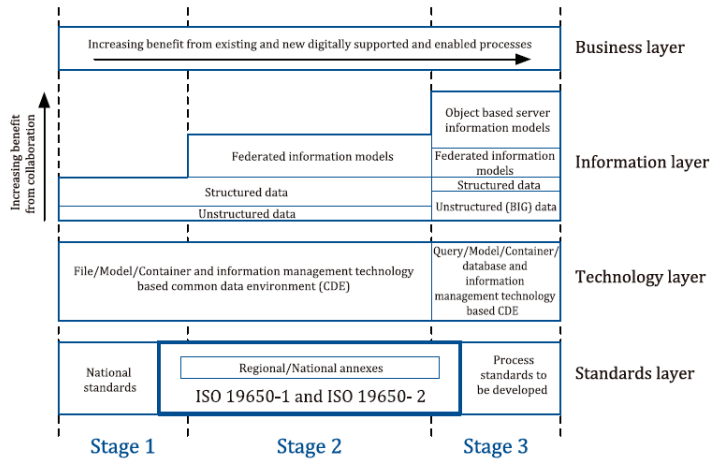


Figure 2.13 (Source: ISO 19650-1:2018)

If talking about Building Information Models (BIM), these can be considered as stage 2, in a more precise concept as a mixture of manual and automated information management processes in relation to an asset or a project. These federate (composite) models are made by different information containers which can be files, systems or information storages elaborated by the different specialty teams, based on their specific tasks.

Then, defined the models according to the stage of the building, the standards develop the information exchange procedure between the different substages of the asset lifecycle, this is towards a Common Data Environment (CDE). To introduce this concept, ISO 19650-1:2018 standard proposes the following definition:

“agreed source of information for any given project or asset, for collecting, managing and disseminating each information container through a managed process”

With the purpose to build this environment is proposed a set of agreements where the information can be understandable and shared by all the parties implied on the process. The standard sets the following agreement points:

- Information formats
- Delivery formats
- Structure of the information model
- The means of structuring and classifying information
- Attribute names for metadata, for examples properties of construction elements and information deliverables.

In addition, the CDE must be accompanied by a workflow process, in which, the information could be stored and categorized according to the development of the work and its use in the different stages of the asset. Following this workflow allows the trail of information in every stage of the project, as well as to know the real status of each task that needs to be developed, enhancing the collaborative working between the different teams involved.

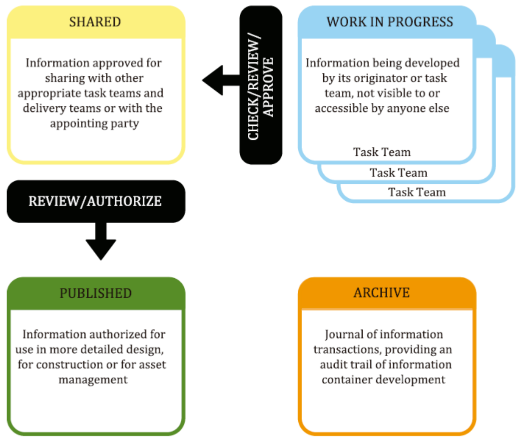


Figure 2.14 Workflow proposed by the international standardization (Source: ISO 19650-1:2018)

Once set the rules in which the CDE can exist to share information and the workflow to be followed, is set the basis of the information cycle that every asset should have since its conception until its final disposal. In the following figures is shown the summarization of these cycles following the compared Level 1 & 2 norms.

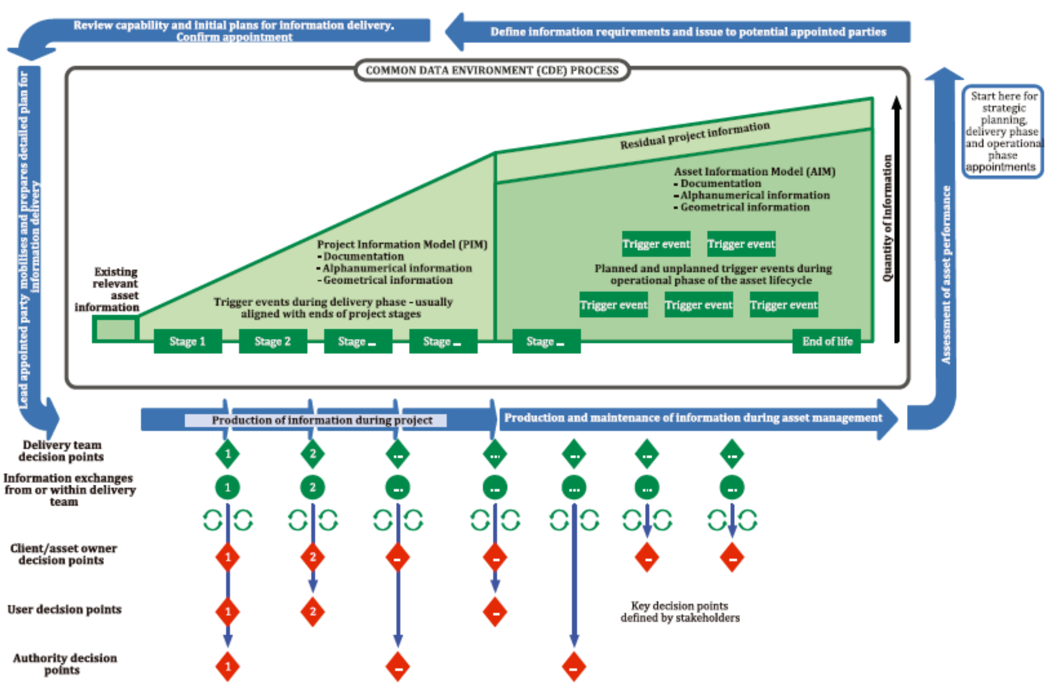


Figure 2.15 Information cycle proposed by the ISO standards (Source: ISO 19650-1:2018)

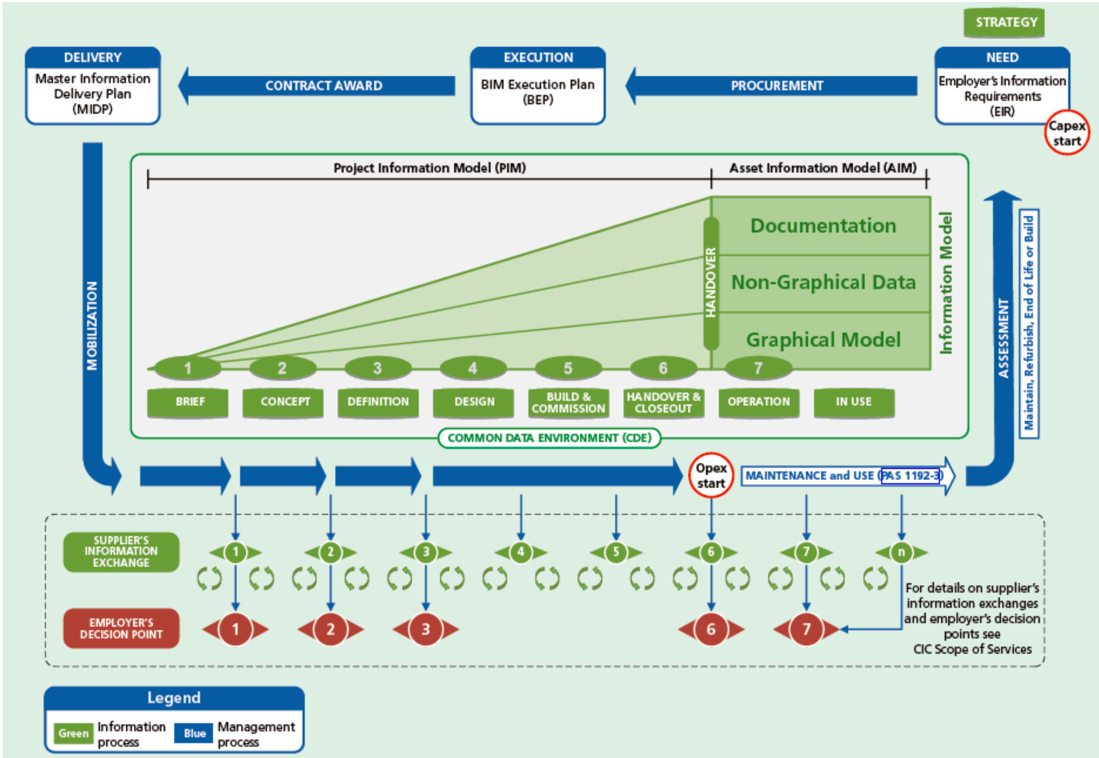


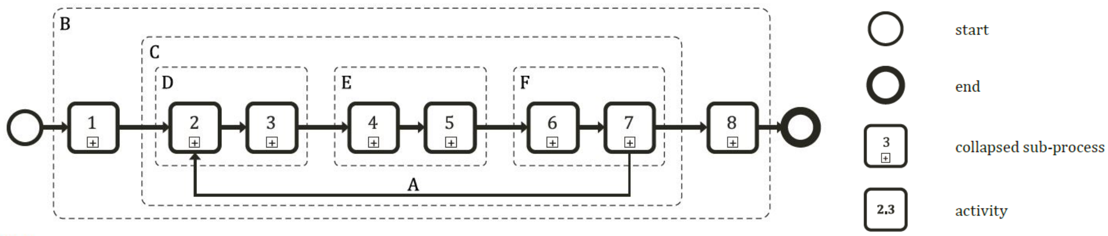
Figure 2.16 Information cycle proposed by BSI standards (Source: BSI PAS 1192-2:2013)

Analysing both approaches inside the CDE, the main difference is the use or not of trigger events during the life cycle of the asset, as ISO 19650-1:2018 standard explains, during the delivery phase these events usually match with the subphases related, therefore BSI PAS-1192-2:2013 proposes a definition of these subphases making the process more traceable. In contrast, during the operative phase of the asset these events can happen randomly depending the conditions in which the project behaves.

While, in the external information sharing process, is noted that level 1 standards offer a more detailed scheme about the different actors with it can be exchanged information until an authority figure, while the level 2 generalizes the processes between suppliers and employers only.

If considered the management process in blue is noted the parallelism of both standards despite the stages involved in each one of them, as in level 1 the explanation approach is related to the information treatment in general, level 2 focus on defined stages to achieve, but at the same time the conclusions to arrive and restart the cycle can be considered the same, always following the standardized workflow explained in previous lines.

Moreover, this group of containers and events need to have a strategy and structure to follow, always based on the EIR and the main purpose to create the information, this is where an organized set of tasks and rules is prepared to allow the interaction between processes and allow finally the information management in the desired stage of the asset. For future references this will be called BIM execution plan (BEP). In the following figure is proposed a workflow where the information management process happens within the frame of ISO 19650-2:2018 standard, based on the project phase of the asset, but could be considered the same approach for the operative phase.



Activities

1 assessment and need
2 invitation to tender
3 tender response
4 appointment
5 mobilization
6 collaborative production of information
7 information model delivery
8 project close-out (end of delivery phase)

A information model progressed by subsequent delivery team(s) for each appointment
B activities undertaken per project
C activities undertaken per appointment
D activities undertaken during the procurement stage (of each appointment)
E activities undertaken during the information planning stage (of each appointment)
F activities undertaken during the information production stage (of each appointment)

Figure 2.17 Information flow towards a BEP (Source: ISO 19650-2:2018)

Looking at the diagram above is possible to see that the BIM execution plan principles must be set since the early project decisions made by the parties, then maturing according with the information level that could be achieved and with the creation of the required information containers for each stage planned for the project. Analysing the NMX-C-527-1-ONNCCE-2017 standard, proposes a list of minimum requirements in which the BIM execution plan can be developed. Therefore, in the next figure will be explained these requirements in its original language.

1. Visión general del plan de ejecución
2. Información del Proyecto
3. Personal clave del Proyecto
4. Requerimientos del dueño para el MIC
5. Metas y Usos MIC
6. Roles y responsabilidades
7. Diagramas MIC
8. Intercambios de Información
9. Estrategia de colaboración
10. Procedimientos de control de calidad de los modelos
11. Infraestructura informática
12. Estructura de los modelos
13. Entregables MIC
14. Integración del MIC al proceso de construcción en general

1. *Execution plan vision*
2. *Project Information*
3. *Project Key personnel*
4. *Owner requirements for the BIM plan*
5. *BIM uses and targets*
6. *Roles and responsibilities*
7. *BIM diagrams*
8. *Information exchanges*
9. *Collaboration strategies*
10. *BIM quality control procedures*
11. *Informatic infrastructure*
12. *Model structure*
13. *BIM deliverables*
14. *BIM integration to the general construction process*

Figure 2.18 BEP information requirements (Source: NMX-C-527-1-ONNCCE:2017)

At the same time, is proposed a flow diagram in which the requirements of this execution plan are correlated and develop the final procedure to follow, including the review and generation loops:

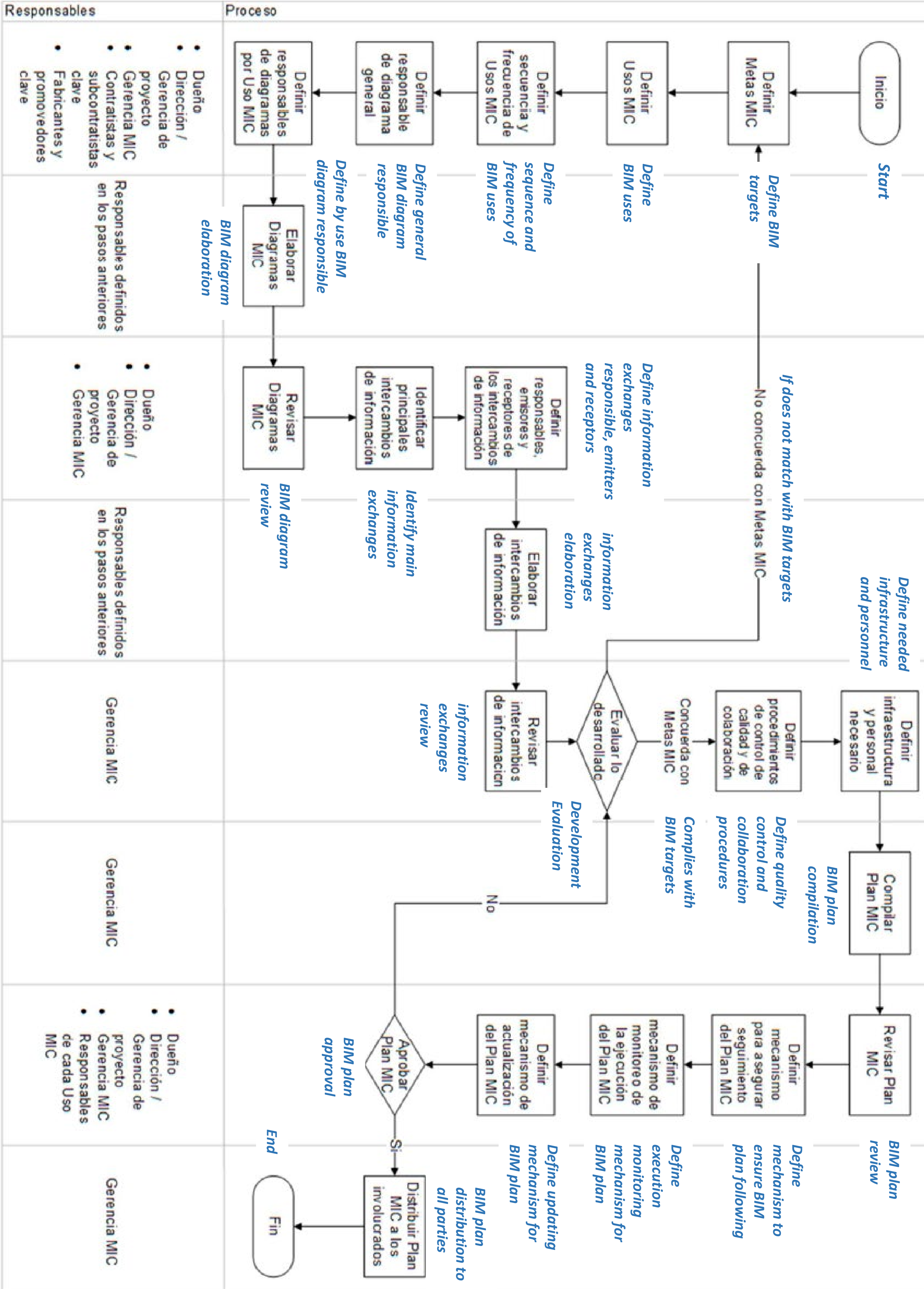


Figure 2.19 BIM execution flow diagram by NMX-C-527-1-ONNCCE:2017

Thanks to the analysis done in the previous standardization layers, it is more feasible to set the basis of a BIM execution plan in the national context, as supported by the definitions and workflows proposed by international standardization , the concepts required to perform the information tasks inside the project become clearer, and fill the possible voids that the national standardization assumes understood or are still under development.

Recalling the objectives stablished in the BIM introduction chapter, it is necessary to focus on the BIM execution plan implementation to support the maintenance issues happening in the national reality, setting the requirements needed to keep the asset in the best conditions during the operative stage of its lifecycle.

Therefore, in the following chapter will be discussed how to set the maintenance plan for built assets, departing from an existing information set that could be considered as a Project Information Model (PIM), and improve it with the information compiled during the trigger events and during site inspections.

In addition, will be considered the work towards the information containers and CDE creation to share files. Regardless the importance that the personnel implied on the project and the structure required to set the different tasks and deliver them to each collaborator, in this study that part will not be considered as is handled more in the organizational part of each asset rather than the constructive one that is the fundamental purpose of this work.

2.5. BIM Execution plans for maintenance.

"An asset is an item, thing or entity that has potential or actual value to an organization. The value will vary between different organizations and their stakeholders, and can be tangible or intangible, financial or non-financial."

"Asset management translates the organization's objectives into asset-related decisions, plans and activities, using a risk-based approach."

Source: ISO 55000:2014

Thanks to these definitions now it can be understood that the information management process should have different approaches according with the different stages of the asset lifecycle, as the variables and objectives change with the time and needs of the involved organization. Consequently, the scope of this chapter consists in giving the key points to develop an execution plan based on the principles of asset management mainframe provided by ISO 55000:2014 standard. According with this, 4 fundamentals need to be followed:

Value

In contrast with the delivery phase approach in which the management is focused on the asset itself, the asset management related to the operational phase must be designed in a way that the asset contributes to give value to the organization in which is involved. This value and its characteristics are defined by the organization and its stakeholders towards the organizational objectives.

Alignment

Once these objectives are defined, enables the organization to take technical and financial decisions and with them, organize the activities and plans to realize the value by exploiting the opportunities and reducing the risks that could happen during the life cycle of the asset, in coordination with the functional management processes.

Leadership

In order to establish, operate and improve the asset management, every level of the organization must be committed and well lead by the managerial levels, this is by implementing a structured organigram defining roles, responsibilities and authorities, in which every component of the organization is able to perform its specific tasks and allowing the interaction and consultation with all the organization levels.

Assurance

As the organization requires an effective management and control, the asset management process must ensure that the organizational objectives designed for the asset are fulfilled, this is by making processes in which the purpose and performance requirements of the asset are linked to the organizational objectives, and allow the monitoring and improving of this correlation.

It is crucial the interrelation of these 4 fundamentals and the features involved in each one of them to comply the purpose of value realization inside the organization. This is the reason why the organization must rely on a structure in which the mentioned objectives and requirements could be fulfilled by a set of plans and tools that allow the interaction and improvement of the tasks developed.

Therefore, is introduced the asset information system concept as a complex in which are included the plans and activities previously mentioned with their development, coordination and control mechanisms during different stage of its lifecycle, in coordination with the asset management policy and objectives.

Moreover, always following ISO 55000:2014 standard, this system needs to be developed and commissioned in such a way that fills the following requirements, aligned with the fundamentals explained above:

- context of the organization
- leadership
- planning
- support
- operation
- performance evaluation
- improvement

Coming back to the scope of the study, which are the constructions as assets and their components, it can be set the correlation of these requirements with the design and execution decisions related to the asset during its entire lifecycle, always departing from the context, organizational objectives and the leadership established by the organization structure.

These structures are needed before any decision related to a design project or existing construction asset is done, as they are the synthesis of the organization needs and value settings that the asset must comply by means of the commented design decisions and plans. As commented in the starting definitions, the asset pursues the objective to give a desired value to the organization, not the opposite.

Analysing then, from the planning requirements stage, is possible to state the first decisions related to an asset towards the Strategic Asset Management Plan (SAMP), in which are developed the principles of correlation between the asset management and the organizational objectives compliance. Once set these rules in which complying the asset requirements is contributing to fulfil the organizational ones, is easier to develop the asset specific and measurable objectives, as well as the activities needed to cover them. For future references this will be called Asset Management Plan.

In terms of support, for this asset management plan and all the activities involving collaboration between the different parties inside the organization, the asset management system must be able to provide the needed information and the exchange channels to develop, verify and improve all the processes needed for the objectives compliance.

As can be seen, every requirement demands a lot of collaboration and resources exchange between all the organization parties, developing very complex and time demanding asset information systems that will not cover only the objectives related to the asset and its performance, but at the same time totally different contexts as the economic, political, etc.

Knowing this and with the aim of having a manageable asset management system for this study, it is decided to go deeper on the asset management plan and its features from the construction point of view, analysing the similarities and differences between the information management plan developed in the previous module. At the same time, this analysis will be managed using the complementary standards ISO/DIS 19650-3:2019 and BSI PAS 1192-3:2014.

If followed the approach of the standards to divide the asset by its life stages (delivery and operational), activity planning and management process needed for maintenance activities must be focused on the needs and performance of the asset in its operational stage, with the possibility to rely or not on existing project information.

Compared with delivery phase planning, where the activities could be scheduled and developed towards and sequence of trigger events that generally match with the project stages, operational phase plans must have the flexibility to plan and execute the activities for scheduled and unscheduled trigger events, having in mind that between the handover and disposal stages, the asset will behave in different ways considering the use, climate and social environments in which is exposed.

As every one of these activities will generate information to exchange between the different parties, the next step inside an Asset Management Plain is to develop the Information Management Plan (IMP), in which will be captured, processed, stored and analysed all the data and information required to comply with Asset and Organizational Objectives. To comply with these requirements, IMP must maintain the information for all the activities involving asset management such as:

- defining asset management strategies and plans.
- implementing asset management plans.
- managing the asset lifecycle.
- acquiring and managing asset knowledge.
- managing the organization and its human resources.
- managing and reviewing risk.

As commented before, this process requires a structured basis of requirements and objectives made by the organization and its stakeholders, starting from the Organizational Information Requirements (OIR) and its transmission in form of instructions to be followed into the Asset Information Requirements (AIR). Furthermore, AIR's must specify the data and information to be captured during the different management activities constituting a specific Asset Information Model (AIM).

In the following chart is displayed the information management process since this organizational planning according with BSI PAS-1192-3:2014.

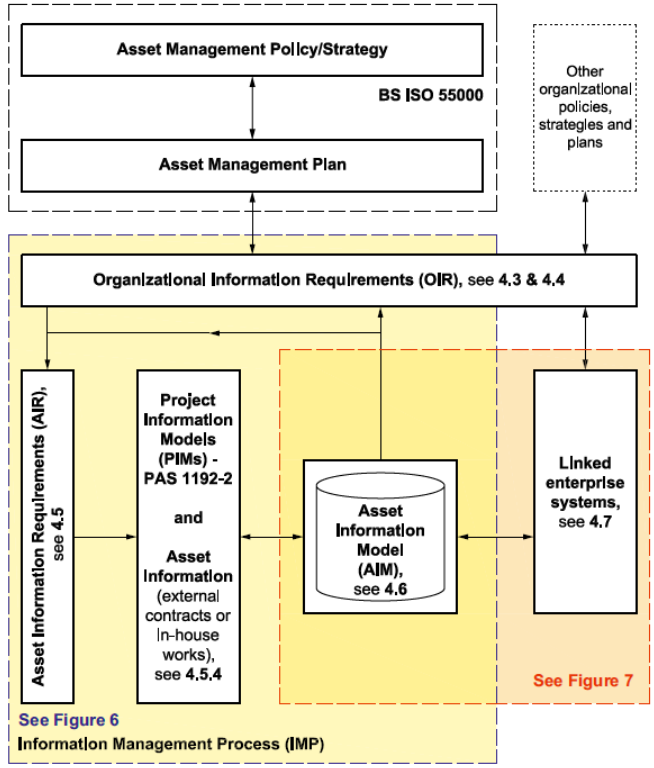


Figure 2.20 (Source: BSI PAS 1192-3:2014)

Moreover, this standard state the fundamental purpose of the AIM, which is fed by different process inside the asset management plan:

"The purpose of the asset information model (AIM) is to be the single source of approved and validated information related to the asset(s). This includes data and geometry describing the asset(s) and the spaces and items associated with it, data about the performance of the asset(s), supporting information about the asset(s) such as specifications, operation and maintenance manuals, and health and safety information."

These feeding processes could be related to other organizational plans, existing project information, or even Project Information Models (PIM) developed during the delivery phase of the asset, but at the same, must allow the input of new data and information from the processes and decisions taken during the asset life cycle.

As a consequence, these information sources must be in constant exchange and control, regulated by a proper CDE, in which all the entering information to the AIM must pass a validation control in order to be shared with all the task teams developing the management activities. At the same time, all the teams generate information which need to pass another control, this time with the compliance with all the OIR and AIR set by the organization. Once this validation is performed the information could be published and archived, or in case of rejection, archive process must continue to have a file history and the improvements done. This is resumed in the diagram displayed in the following figure.

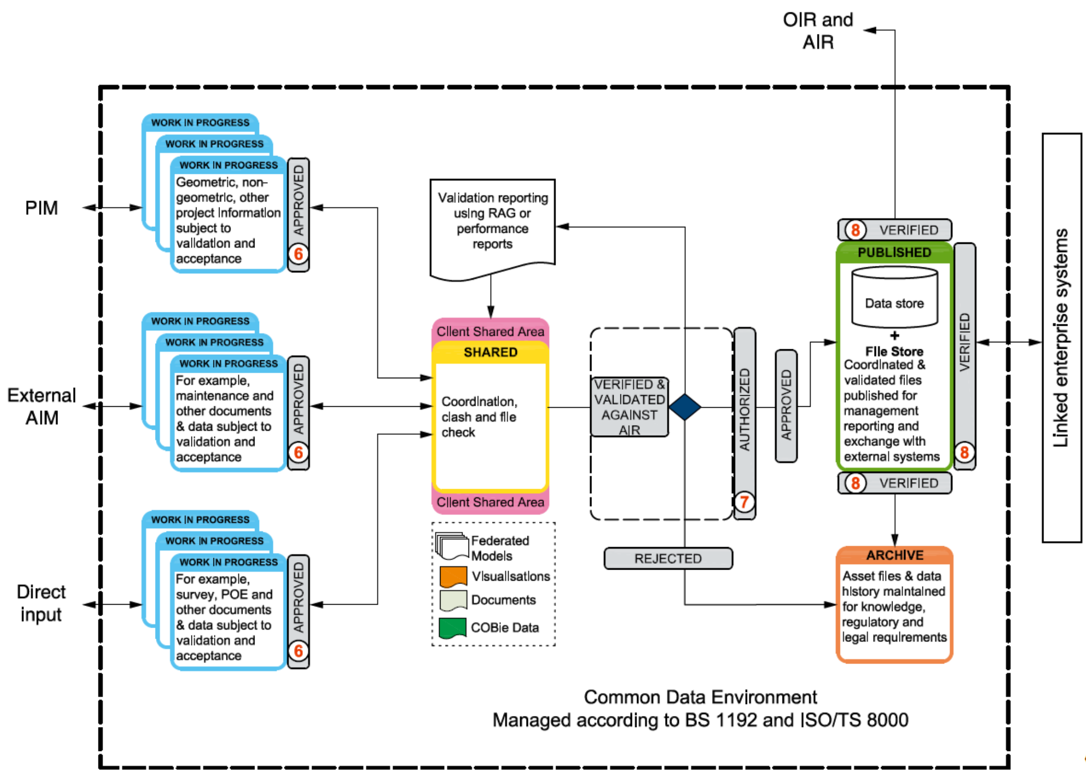


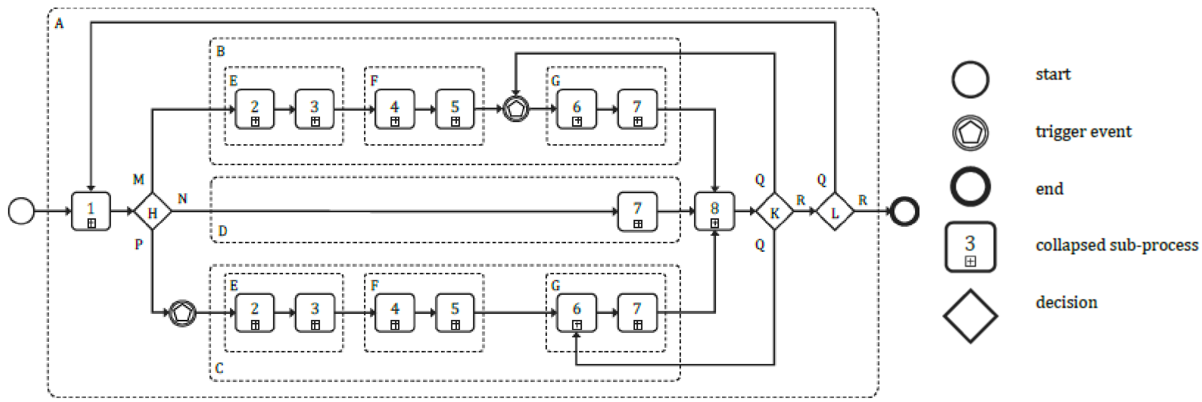
Figure 2.21 CDE Information diagram (Source: BSI PAS 1192-3:2014)

With this structure developed, the management plan is able to provide the AIM the only source of information status required, combining the information from all the asset stages and allowing to follow a trace of each task performed, analyzing the decisions taken at the moment and the possible improvements that could be done in future processes.

In addition, one of the most important benefits of using this CDE, is the possibility to take better decisions and therefore make better processes and tasks, as every party of management team have sufficient information resources to plan and execute tasks focused on dealing with planned and unplanned trigger events to be occurred in the asset.

This duality of events may represent a challenge in the information system, as the appointments inside each event will need to be performed in a planned or a reactive way according with the inherent characteristics of each trigger event. If these activities are not registered in the proper way established in the AIM, can cause information losses or untraceable voids that can affect the effort done by all the interested parties and the organization.

For this purpose, ISO/DIS 19650-3:2019 explains the workflow to be carried out inside the AIM considering that the trigger events could happen in different planning conditions, as well as the information management sequence to follow based on the different appointments in which the asset needs to provide information and feed the AIM to take better decisions related to the asset management.



Key:

Information management activities

1. assessment and need
2. invitation to tender/ request to provide service
3. response to invitation to tender/request to provide service
4. appointment
5. mobilization
6. production of information
7. information model acceptance by appointing party
8. AIM aggregation

Activity groupings

A. activities undertaken during the asset lifecycle
B. activities undertaken for each appointment made before trigger event
C. activities undertaken for each appointment made after trigger event or project using ISO 19650-2
D. activities undertaken when acquiring an asset
E. activities undertaken during the procurement stage (of each appointment)
F. activities undertaken during the information planning stage (of each appointment)
G. activities undertaken during the information production stage (of each appointment)

Decision points, questions and actions

H. type of trigger event providing information
K. continuation of the appointment
L. continuation of this information management process
M. via an appointment made before a trigger event
N. received from another appointing party/asset owner
P. via an appointment made after a trigger event or project using ISO 19650-2
Q. yes
R. no

Figure 2.22 (Source: ISO/DIS 19650:3:2019)

After analysing the diagram, it is possible to consider general maintenance as a process in which the asset changes and a new information process needs to be developed, therefore becoming the trigger event under study, and the activities and processes needed to maintain the asset and comply the AIR as the appointments constituting the trigger event.

Appointments for maintenance must be defined based on a deep knowledge of the operative asset, for buildings this imply to retrieve as much information as possible from all its lifecycle stages, departing from the analysis of the current state and its concordance with what is expected from it in the OIR and AIR developed by the owner organization.

For instance, a good starting point could be the “as built” project required for every asset to operate. This information package must contain all the data related to the different specialties involved in the asset construction and its operation requirements. Focusing on the general requirements to deliver this package according with Mexican law context, can be mentioned the following specialties:

- Asset purpose and objectives
- Architecture (Plans and project)
- Structure (Plans and calculations)
- Technological Solutions (Drawings and materials brochures)
- Constructive process log files
- Hydraulics and plumbing (Plans, specifications and calculations)
- Electric project (Plans, specifications and calculations)
- HVAC or heating systems (Plans, specifications and calculations)
- Product brochures.
- Construction costs analysis
- Operation costs
- Operative plans and schedules

Additionally, if information packages from previous delivery phases are available, should be registered and documented with the purpose to have a more reliable data base, compiling the complete building history considering all the modifications since the conceptual design until the final handover. This step will depend entirely on the information provided by the organization and the development reached by the project information on each stage.

Secondly, a comparison from “as built” project against the current state under operation shall be done to avoid any information void and knowing that the asset might suffer modifications derived to the daily use. This process can be done by physical inspections on site, with the delivery requirements and formats approved by the AIM.

Thirdly, this information package must be validated to be considered as an AIM component, by the criteria of direct input information, existing AIM or PIM. This will depend on the technological approach employed during the information generation and the organization level inside the asset management system.

Once inside, this information package becomes a shared component and can be complemented with other coexistent information plans, this is useful to define the different contexts (i.e. physical, social, economic, organizational) which may influence the behaviour and operation of the asset, affecting directly the life cycle and the design life expected for the construction.

In order to determine the design life of the asset, lifecycle planning must be performed to ensure that the construction and its components service life exceed the designed life for which was created, under the operation and context provided by the organizational requirements. ISO 15686-1:2011 standard sets the principles in which this activity must be planned and executed, considering the following topics:

a) the likely performance of the components of the building within the building life cycle in the expected external environment and conditions of occupancy and use
b) the life-cycle cost and environmental impact of the building over its life cycle
c) c) operating and maintenance costs

d) d) the need for repairs, replacements, dismantling, removal, re-use and disposal, and the costs of each

e) the construction of the whole building, installation of components and the maintenance and replacement of short-life components.

At the same time, this standard establishes the principle of implementing the service life planning since the very early delivery phases of the asset, considering that every decision made in the different stages will affect the intended design life of the components and the building itself.

Inside this principle, is considered the maintenance plan as a process in which the different components receive cyclical, reactive and refurbishment maintenance activities to keep the asset in the desired conditions. For this activity is needed to know the service life of each component and its defective performance factors, which can be retrieved from all the information processes happening in the CDE.

According with ISO 15686-4:2014, lifecycle conditions for existing assets are crucial to define if the expected design life would be reached or not by the proposed constructive solutions, being affected by different factors:

"At later design stages and during construction, when the configuration and location of products has been fully established, it becomes possible to analyse the service life of products according to 'in use' conditions. These conditions can vary the reference service life depending on factors such as exposure to weather, aggressiveness of the local environment and other degrading (or upgrading) factors. The result of applying in-use conditions is to define an estimated service life which is simply the length of time of a product occurrence lifecycle."

This is why this information structure becomes fundamental at the time to take relevant decisions, as inside the context information can be identified the factors that could develop a misfunction in the different construction components, setting the different failure causes and register the way of manifestation, so they can be identified and measured easily during an inspection. These failures shall be categorized by its consequences and the impact that may have in the asset performance, like the hierarchy shown in the following figure:

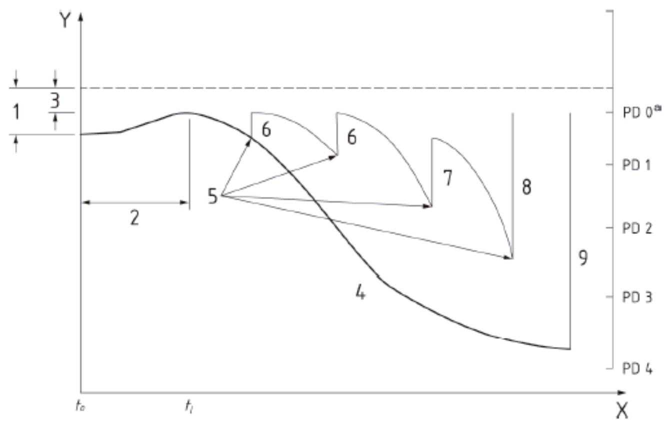
Table B.2 — Suggested hierarchy of safety consequences

Category	Consequence	Example
1	Danger to life	Sudden collapse of structure
2	Risk of injury	Loose stair tread
3	Danger to health	Serious damp penetration
4	Costly repair	Extensive scaffolding required
5	Costly because repeated	Window hardware replacement
6	Interruption of building use	Heating failure
7	Security compromised	Broken door latch
8	No exceptional problems	Replacement of light fixtures

Figure 2.23 (Source: ISO 15686-1:2011)

Moreover, once defined the failure causes and its consequences, there can be provided specific solutions and action plans to maintain the asset in the best possible conditions, in accordance with the operative schedules and the life span of each component.

These tasks and their way to be implemented shall be reflected on an activity calendarization in which can be set priorities and resources according with the previous categorization, so the maintenance decisions are information based and unexpected situations can be handled in a better way. This will help the organization to achieve its objectives in a more efficient way and to realize the value required.



Key

Y	quality/function	7	refurbishment or repair
X	time	8	replacement
1	expectation/achievement gap	9	renewal
2	commissioning		
3	initial performance gap	a	Performance degrees (PD) are defined in 5.3.4.2.2.
4	performance without preventative actions	t_0	time of initial "as built"
5	limit states	t_i	time at start of "in-use" (operation & maintenance) stage
6	preventative and periodic maintenance		

— Performance degree 0: No symptoms

— Performance degree 1: Slight symptoms

— Performance degree 2: Medium

— Performance degree 3: Strong symptoms

— Performance degree 4: Totally unacceptable, including collapse and malfunction

Figure 2.24 Operative lifecycle performance diagram for constructions (Source: ISO 15686-7-2017)

To have a better understanding about the impact of the maintenance activities developed inside a maintenance plan is important to analyse the performance of the construction along its lifecycle stages. Therefore, ISO 15686-7:2017 standard sets a plot in which can be seen a suggested set of stages during the operative life of the building, starting from the commissioning when all the construction is nearer to reach the ideal targets of the AIR and OIR (dashed line), to then start the decay of the performance due to the age factor or the operational tear and wear.

This decay process will have different consequences when developing or not maintenance activities, in bold line is shown the expected performance with no preventive actions until a total failure happens, needing a total refurbishment, wile, in the light line can be seen the approach using preventive maintenance, in which by means of inspections and performance degree criteria, the decay happens in a more controlled way, avoiding that the performance vs expectation gap become so big that the total performance of the building is compromised and in consequence the expected service life.

Both situations will have also an important impact at the time to assign time and resources to develop the maintenance activities, as preventive approach will contribute to have less costly activities and organized in different time periods so the resources can be planned efficiently, as well as to have less invasive activities that could obstacle the daily operation of the building, causing unnecessary closures.

All the procedures involved in the maintenance alongside other trigger events require a robust model where all the information processes and exchanges can happen on an efficient way allowing the interoperability between all the interested parties, but at the same time, keeping the principle of the AIM to be single source of information required on the operational life of the asset.

Nowadays, with the technology development, is possible to comply with this targets using Building Information Models (BIM), as its structure allows to have a lot of processes done in the information plan (performance, delivery, operation) encapsulated in form of geometric elements , which in the case of buildings are the constructive components. Thanks to this organized structure inside the BIM, is possible to register information about the different activities developed in each geometry and its subcomponents from past or future events.

For this reason, is fundamental that the entity in charge of developing the AIM and its components have this in mind, focusing in define the main constructive components of the asset from which all the information process can flow and be shared for the different activities and stages of the building lifecycle.

By the purpose of this study, will be analysed an existing building in its operative phase, in which, due to a change of administration, is required to develop an information process to know the current state of the construction, and departing from this, the maintenance plan to be executed for the remaining lifecycle of the asset.

Taking advantage of the technology, this plan will be based on a BIM approach, designing the model from the legacy documents and plans provided by the constructor in charge. For this, will be identified all the constructive components which can become the geometry information containers, and then generate all the information process structure.

Furthermore, all this legacy information will be validated against a physical inspection of the building, detecting any mismatch and failures due to the age and operation process, following the same constructive components encapsulation, to then propose the activities to be developed.

In addition, is necessary to understand the organizational point of view and review with the new administration will keep the OIR and AIR instructions, or it will be handled a significative change in these structures, as the value pursued for the AIM might suffer modifications.

3. Case study.

With the objective to apply the Building Process and Information Management (BPIM) in the Mexican context, it is necessary to have a real construction where it is feasible to get as much information as possible and to know the current state of the building after a portion of its life cycle has happened.

Consequently, it is decided to use a medium size school inserted in semi urban context, in which, with help of the owners and project architect, it was gathered information since the design and construction stages, and now, inspections can be made in order to determine the current performance of the construction and its possible maintenance strategies.

Centro Educativo Estado de Hidalgo (CEEH project for future references) is an institute that provides elementary education at different levels according with the Mexican education program (for students from 5 to 15 years old) and has been providing services since 1989 in the municipality of Santiago Tulantepec de Lugo Guerrero, Hidalgo, Mexico.

Currently provides educational services to approximately 200 students in its different levels, but formerly, CEEH started operations in different locations based on the student demand and the spaces available in the community,

Later on, with the growth of the education need and demand of space, the owners decided to plan and build the actual location of this institute starting the construction on September 25th, 1994 and begin operations on September 5th, 1995 until our days. In the following figures is shown the evolution of the project, as built and current state.

Figure 3.1 Project mockup, considering possible expansions towards the north-west orientation (left side of the image) (Source: CEEH photographic register)

Figure 3.2 As built state, with the main unit finished and the expansions postponed for future growth. (Source: CEEH photographic register)

Figure 3.3 Current state, during the inspection done in January 2020 (Source: CEEH photographic register)

In its almost 25 years of service life, the building has suffered slight modifications respect from the original project, due to the adaptation of some spaces to cover specific operation needs. To model BIM, plans from the most recent trigger event will be taken as basis, alongside the original project information.

This trigger event consisted in the change of school administration after these 25 years, therefore, the new administrators in collaboration with asset owners decided to generate current state plans and inventory in order to comply with the legal requirements of the National Public Education Secretary (SEP).

As well, both parts agreed the organizational and asset requirements for this new phase of the construction, leaving the AIR unchanged and in charge of the asset owners. Applying the terms provided by the previously analyzed standardization , is possible to identify the construction owners as the organization, with a well-defined structure and clear value objectives referring to the asset, which are summarized as:

- Social: As education is vital in each worldwide community, if the school is able to operate and bring its services for a longer time, and therefore, more generations, the organization gains value providing such an important service to a specific society.
- Economic: With this building being operative and with acceptable performance along its lifecycle, the investment done by the organization is recovered and the value is increased when the operation could be done without interruptions and the profit is maintained.
- Architecture-constructive: If all the constructive components of an asset are identified and inspected with the aim to work as close as possible to the project expectancies, fewer operative costs could be achieved and the value gain is based on having a building with a high capital gain for the organization.

Having in mind these concepts of value, the organization established the need for a system in which all the processes related to keep in good performance the building components of the asset, so the daily operations inside the school could be performed normally during the major part of the lifecycle.

Therefore, is proposed to the organization the implementation of an information management process based on BIM, in which all the tasks could be set and managed efficiently, thanks to the geometry information container explained in the previous chapter.

With the purpose to set the basis in which the BIM will be modeled, there will be studied three main categories of the asset.

- Firstly, analyzing the architectural project since its conception until its current use modifications.
- Secondly, the surrounding context pointing mainly on the climate and social aspects in which could be found any possible defective performance factor.
- Thirdly, the technical solutions adopted to build the project with the purpose to define the constructive elements (geometries in BIM) to be analyzed and its material layers to determine probable failing cases.
- Finally, an inspection of the asset will be handled and documented with the information results of the previous analysis topics.

3.1. Project and Space Distribution.

Since its design conception, the principal aim of the project was to cover the different levels of the national elementary instruction, providing spaces to cover the needs of the students according with the growth of the groups and the changing needs of each level. The academic offer consists of the following stages based on the children's age:

- Kinder (4 to 6 years old)
- Primary (6 to 12 years old)
- Secondary (12 to 15 years old)

With this established, the current building provides a total usable area of 663 m^2 organized in 3 levels including administration and services. Nevertheless, during the compilation of documents to make the information model, it was fundamental to implement an organization criterion to define the different spaces by their current use taking advantage of the architectural plans available.

Therefore, to establish a categorization based on the use of the different spaces, it is proposed a sector organization, in which all spaces can be classified according with its main function. The results obtained from this task are displayed in the architectural plans shown below.

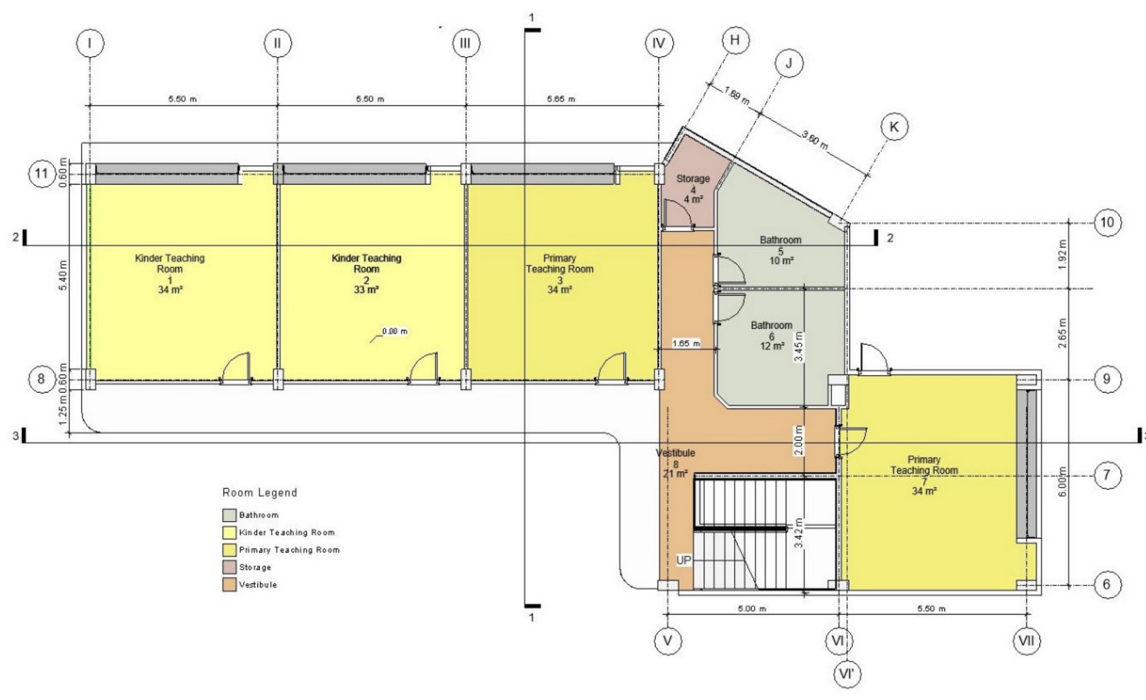


Figure 3.4 Ground floor distribution (Teaching and services) (Source: CEEH-BIM-XX-05-07: Maintenance model)

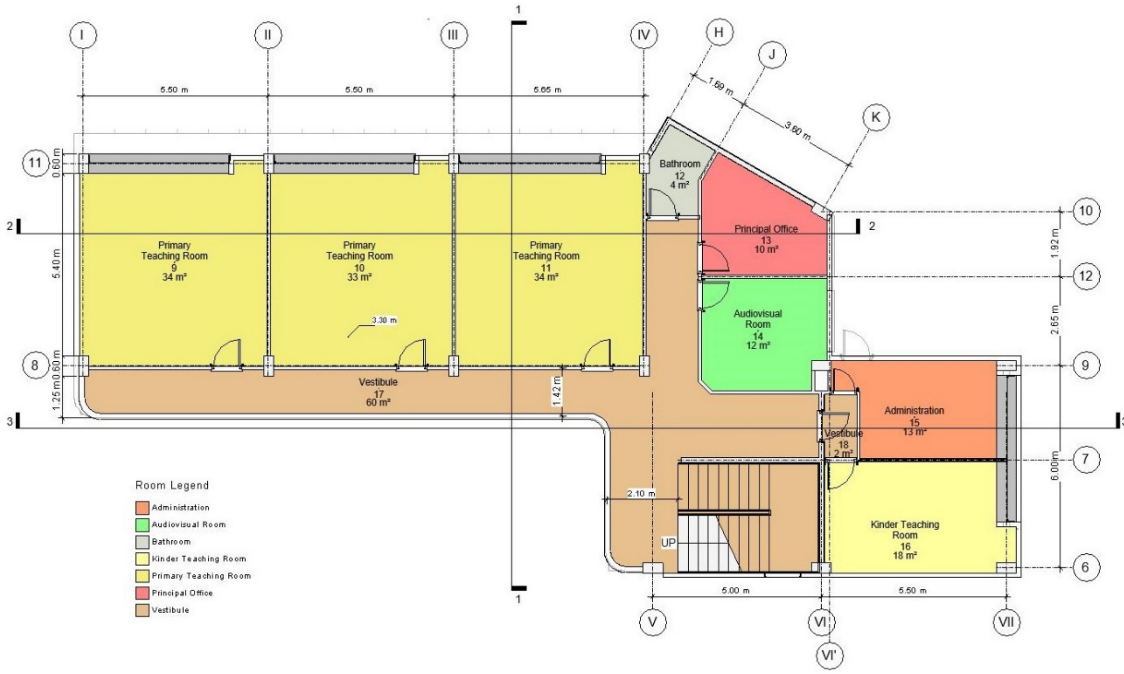


Figure 3.5 First floor distribution (Teaching and administration) (Source: CEEH-BIM-XX-05-07: Maintenance model)

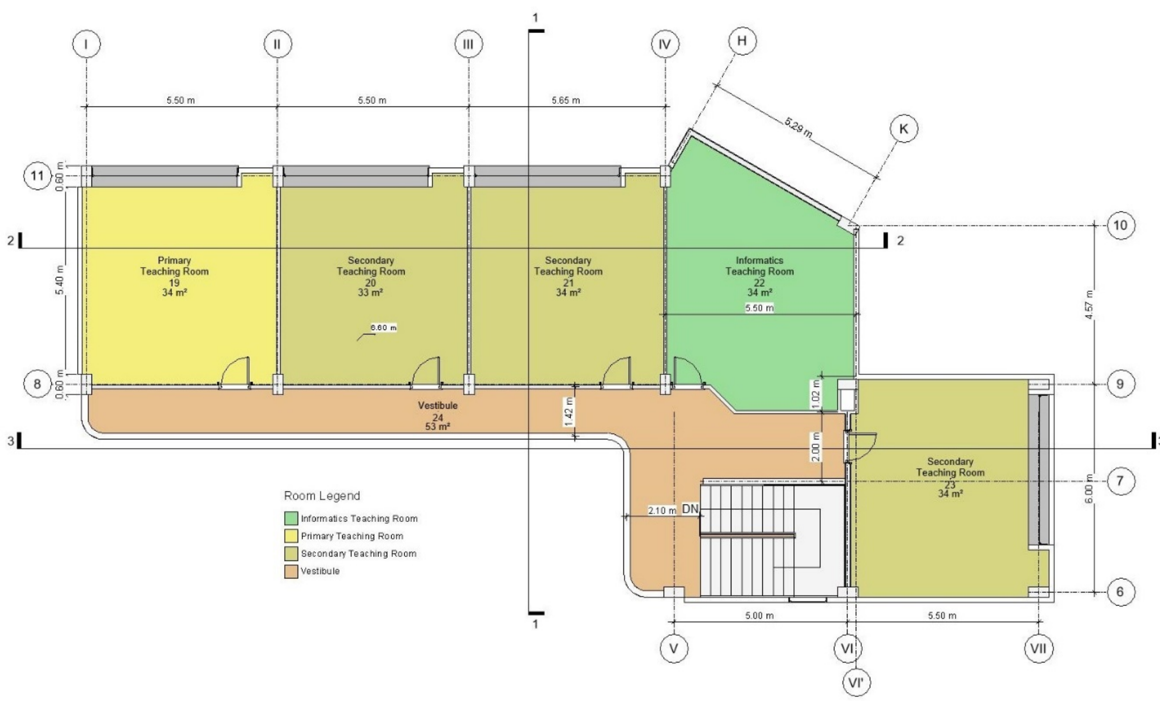


Figure 3.6 Second floor distribution (Teaching) (Source: CEEH-BIM-XX-05-07: Maintenance model)

Consequently, with the sectorization established, it was analyzed the usable surface by floor and by the different sectors, checking the data to be consistent between the partial and total areas, the results obtained after the modelling were the following:

Room Schedule			
Name	**Number**	**Area (m^2)**	**Level**
Kinder Teaching Room	1	34	Level 1
Kinder Teaching Room	2	33	Level 1
Primary Teaching Room	3	34	Level 1
Storage	4	4	Level 1
Bathroom	5	10	Level 1
Bathroom	6	12	Level 1
Primary Teaching Room	7	34	Level 1
Vestibule	8	60	Level 1
Total level 1		**221**	
Primary Teaching Room	9	34	Level 2
Primary Teaching Room	10	33	Level 2
Primary Teaching Room	11	34	Level 2
Bathroom	12	4	Level 2
Principal Office	13	10	Level 2
Audiovisual Room	14	12	Level 2
Administration	15	13	Level 2
Kinder Teaching Room	16	18	Level 2
Vestibule	17	60	Level 2
Vestibule	18	2	Level 2
Total level 2		**220**	
Primary Teaching Room	19	34	Level 3
Secondary Teaching Room	20	33	Level 3
Secondary Teaching Room	21	34	Level 3
Informatics Teaching Room	22	34	Level 3
Secondary Teaching Room	23	34	Level 3
Vestibule	24	53	Level 3
Total level 3		**222**	
Total Area		**663**	

Room Total Schedule	
Name	**Area (m^2)**
Kinder Teaching Room	85
Primary Teaching Room	203
Secondary Teaching Room	101
Informatics Teaching Room	34
Vestibule	175
Bathroom	26
Principal Office	10
Audiovisual Room	12
Administration	13
Storage	4
Total	**663**

Figure 3.7 Surface per room chart. (Source: CEEH-BIM-XX-05-07: Maintenance model)

In addition, and to complete the architectural component of the project, the different elevations are displayed considering as reliable as possible the finishing and state observed during the physical inspection

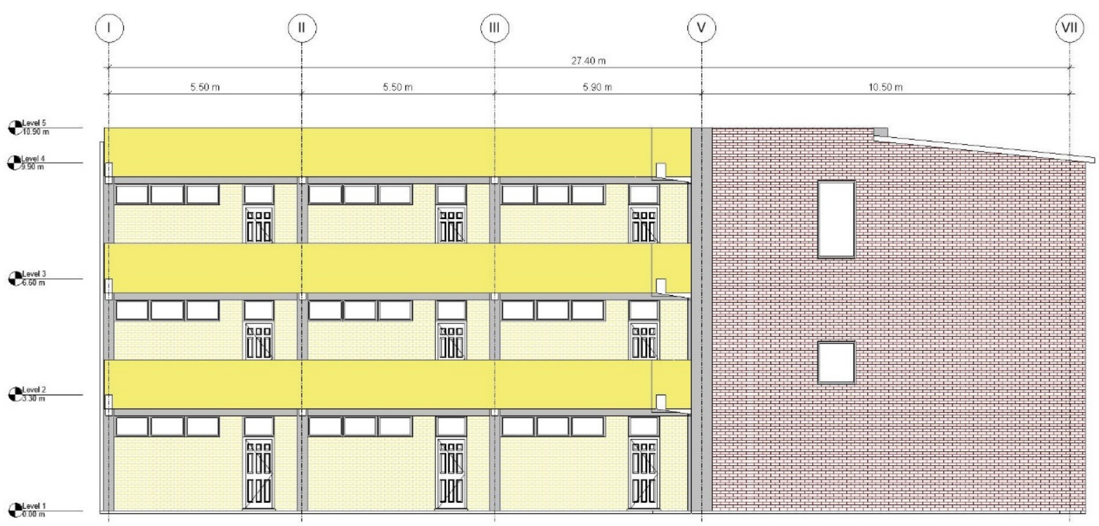


Figure 3.8 North west elevation (front). (Source: CEEH-BIM-XX-05-07: Maintenance model)

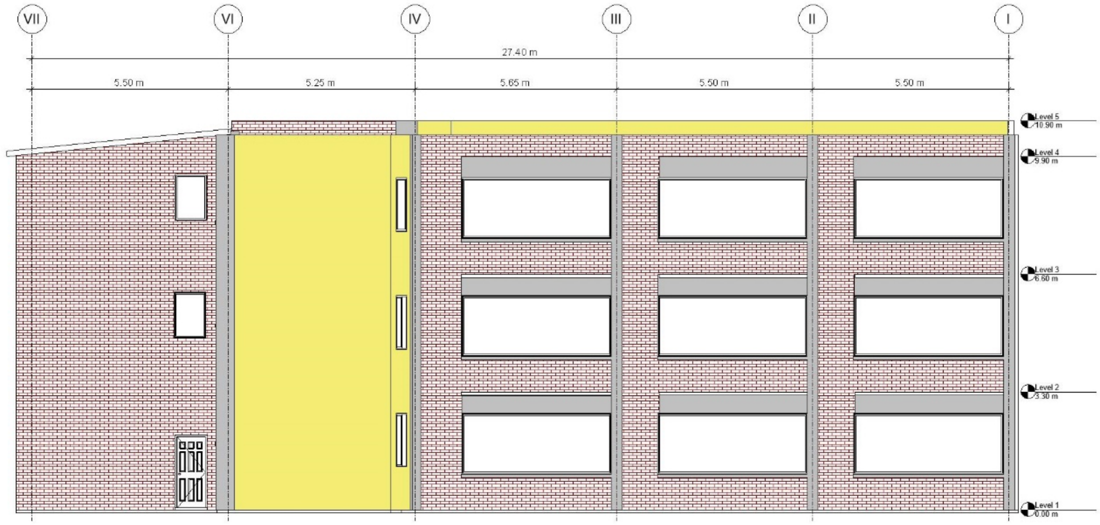


Figure 3.9 South East elevation (back). (Source: CEEH-BIM-XX-05-07: Maintenance model)

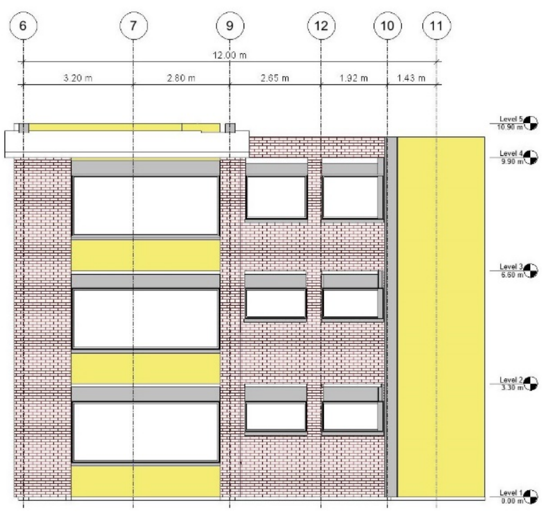


Figure 3.10 South West Elevation (Lateral). (Source: CEEH-BIM-XX-05-07: Maintenance model)

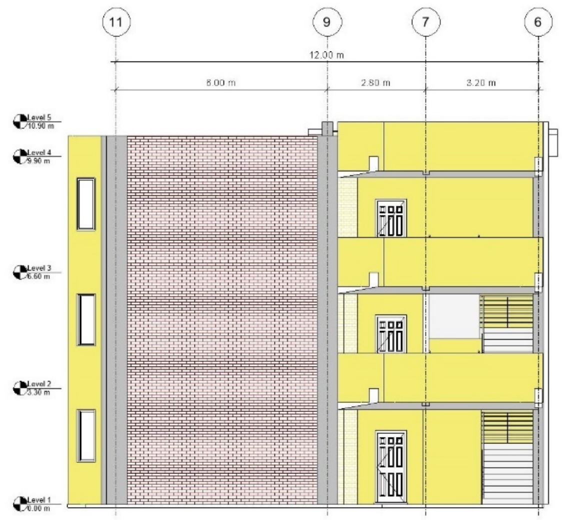


Figure 3.11 North East Elevation (Lateral). (Source: CEEH-BIM-XX-05-07: Maintenance model)

To be consistent with the legacy information provided by the organization, elevations and grids were kept the same in the BIM. Meanwhile, the orientation of each component will be assigned by an item codification to be developed in later stages.

From the architectural point of view, it can be considered as conclusion that the space distribution changes during the elapsed life time of the building did not modify substantially the main purpose of the construction, and the modifications done in some sectors as the administrative, were done with the correct supervision, leaving the elementary building components with very few or null affectations.

The space sectorization established in this section will be helpful at the time to develop other classifications related to the specific construction components, as the codification of each closure to be identified and managed inside the information system.

With these conclusions said, the following step will be to analyze in a deeper form the construction itself, now from the different components that could form the geometry information containers required in the BIM under development.

3.2. Technological solutions.

If compared with the highly technological systems provided in more developed countries, solutions applied into the Mexican context can be considered very basic and even archaic, but at the same time, keeping in mind that constructive systems are developed to serve the specific needs of each place, it is appreciated the highly skilled workforce required to execute this kind of work, even could be considered as art craft due to the predominance of the empirical execution in different constructions rather than to follow a standardized procedure as recommended by the standardization.

Therefore, it is important to set a middle point between both situations in Mexico, taking the best of the two ways of working in order to implement a methodology where empirical work and information management strategies can coexist and avoid field mistakes and loss of track during the constructive process.

Focusing on CEEH, and having in mind the school space requirements provided by the architectural project, the solutions to be provided shall be easy to maintain and durable for the activities developed with the students, as well as a structure that allows large spans for the free plan classrooms.

Therefore, the architect in charge proposed constructive elements according with the local skill and technology context, trusting in the workforce capability, choosing brick walls with different finishes and purpose as well as a structural system based on reinforced concrete columns and beams, and poured concrete slabs supported between beam spans with steel joists.

In terms of construction finishes, were considered simple mortar layer with acrylic paint for the interior walls and ceilings, while for the rough operation use of the school floor, the picked choice was granite-cement tiles washable and resistant.

Following the previous sections approach to generate information in a way that can contribute for the BIM model, was decided to analyse these technological solutions applied to the project and then, define the constructive elements that could encapsulate all the processes inside the BIM.

As the scope pretended is to analyse the main construction components, window and door openings are considered into the BIM creation, but as reference using generic solutions, these elements could be detailed in later processes counting with the BIM developed for this study, In the following figures can be observed the different constructive typologies observed during the inspection and in which will be based the cross-section analysis. Next, mentioned sections will be analysed and commented.

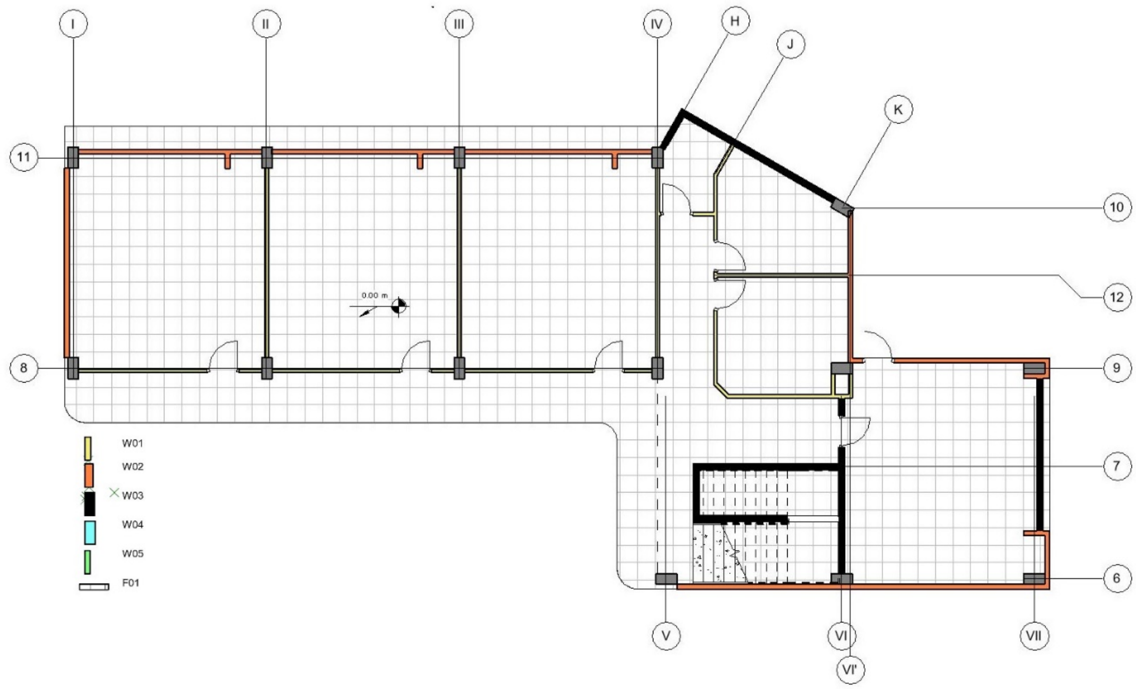


Figure 3.12 Constructive typologies ground floor (Source: CEEH-BIM-XX-05-07: Maintenance model)

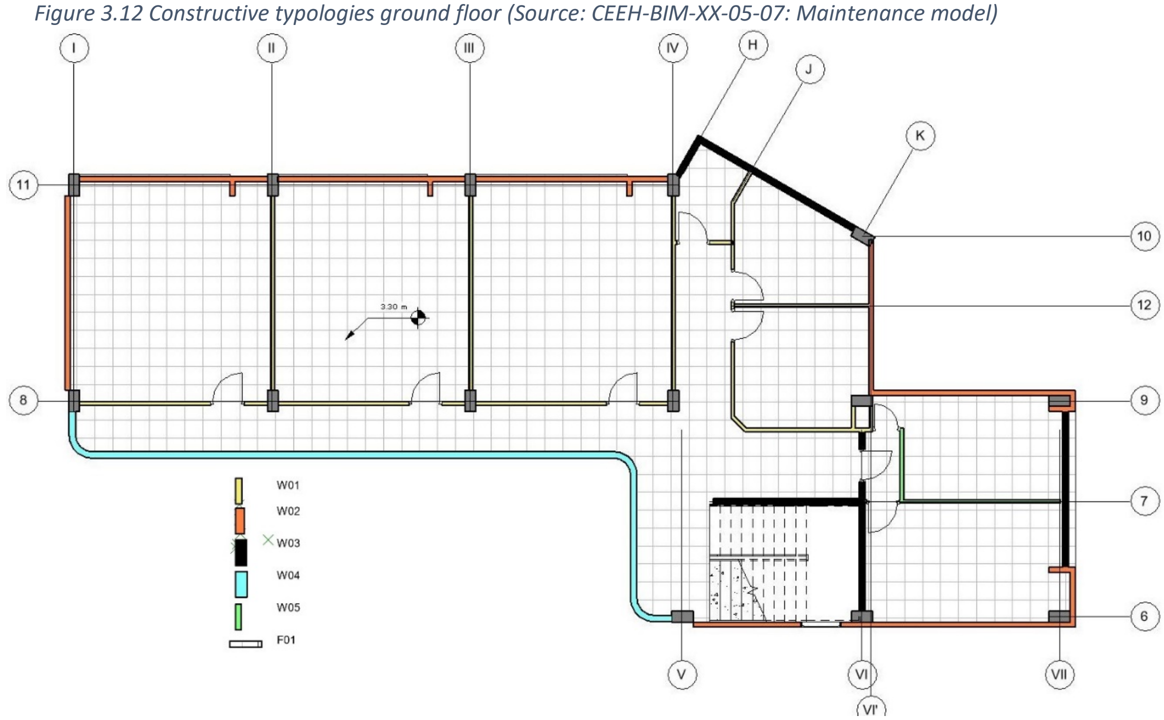


Figure 3.13 Constructive typologies first floor. (Source: CEEH-BIM-XX-05-07: Maintenance model)

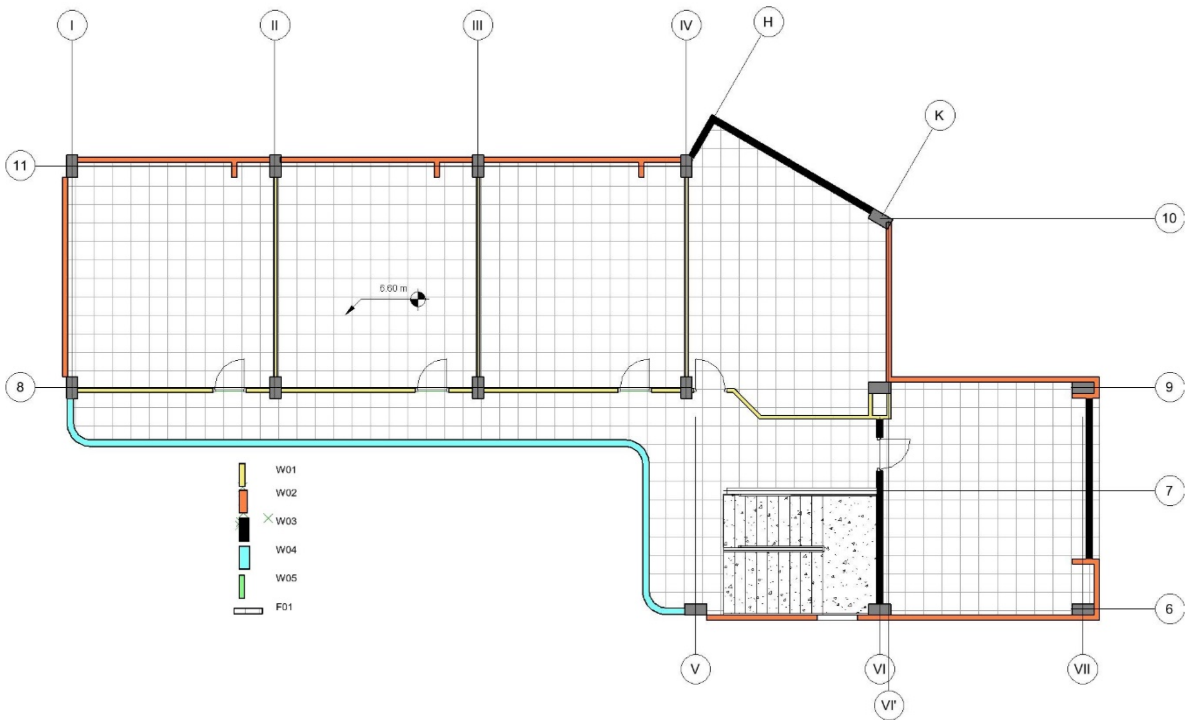


Figure 3.14 Construction typologies second floor (Source: CEEH-BIM-XX-05-07: Maintenance model)

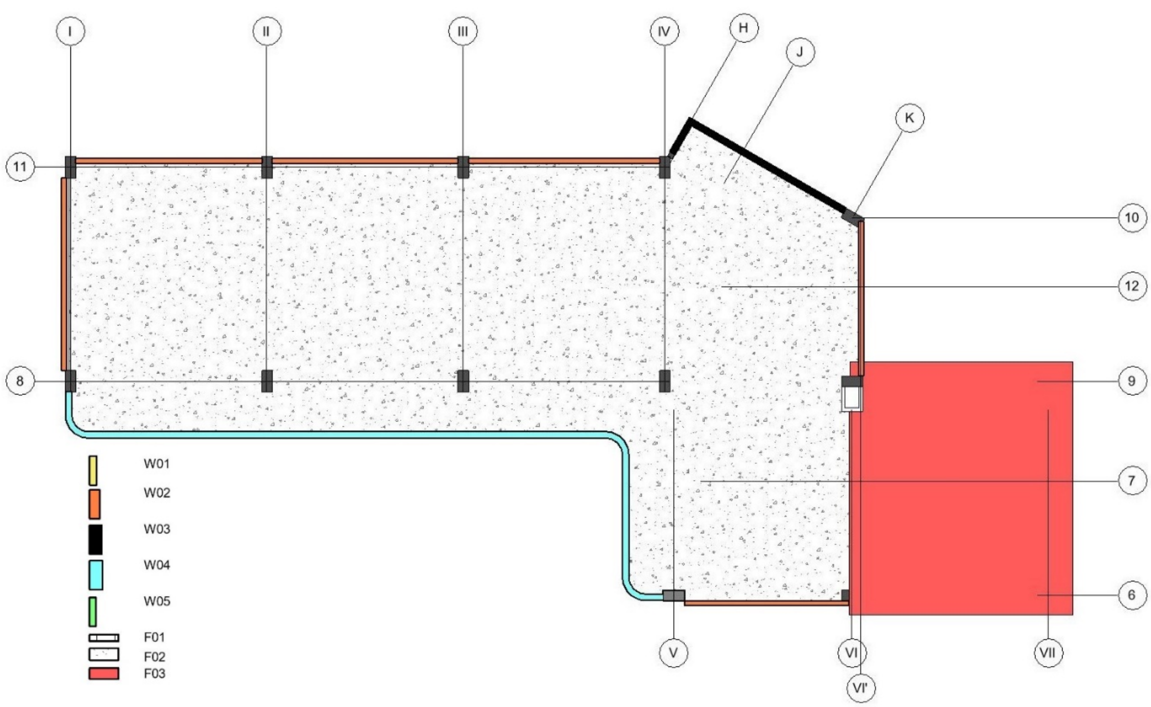


Figure 3.15 Constructive typologies top floor. (Source: CEEH-BIM-XX-05-07: Maintenance model)

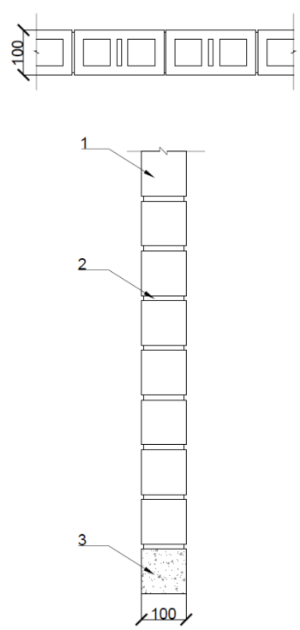
As noted in the plans, with help of the legacy photographic record of the construction process and the physical inspection it was decided to set 5 different wall typologies, as well as 3 slab/roof types, giving and identification code to define the locations by floor and later be assembled in the BIM.

Once having these solutions identified in the project, there were analyzed the different material layers constituting each component, with the purpose to generate the main cross sections to be used in the information management process. As some of the products that will be displayed inside the mentioned sections are produced locally or it is missing the performance data, this could cause performance variation that are not so easy to predict during the life cycle of the building. In order to fill this information void will be considered similar products inside the Mexican context only to have reference values.

While, for the standardized materials coming from certified manufacturers, it will be used the information provided by the product brochures, having the reliance required as they are not only certified by ASTM test procedures, but at the same time, some of them are following the national certification provided by the national ONNCCE quality standards

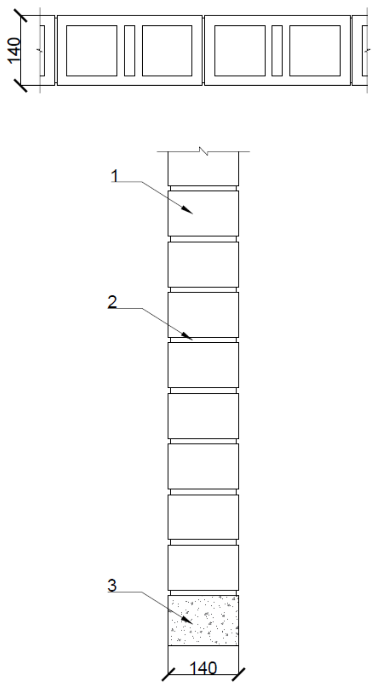
Identification and materials found during this task are displayed in the following pages.

External glazed brick wall W01



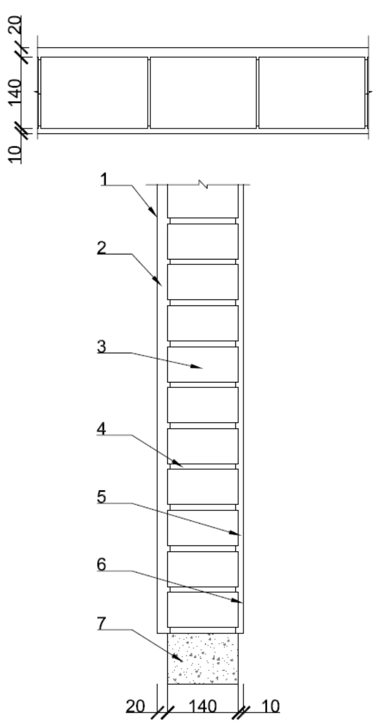
External Wall W01		
Layer	**Description**	**s (m)**
1	Glazed Brick (0.2x0.1 m) Santa Julia	0.1
2	Joint Mortar	0.005
3	Foundation beam	0.1

External exposed brick wall W02



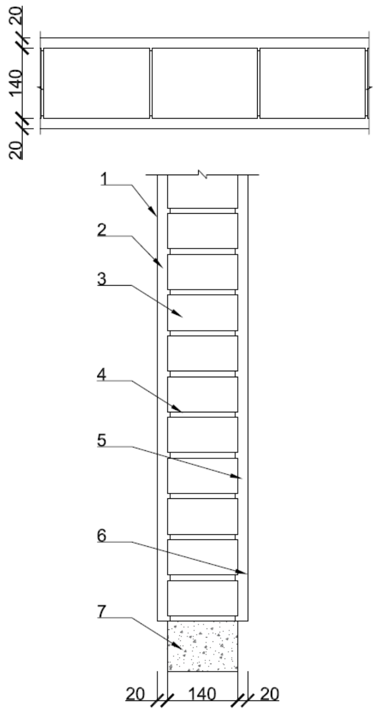
External Wall W02		
Layer	**Description**	**s (m)**
1	Extruded Brick (0.29x0.09 m) Santa Julia	0.14
2	Joint Mortar	0.005
3	Foundation beam	0.15

External- Internal mortar finished wall W03



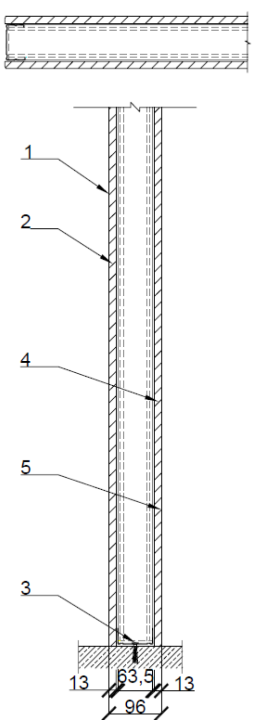
External Wall W03		
Layer	**Description**	**s (m)**
1	Acrylic painting for exterior and interior	0.000075
2	Exterior rough Finishing mortar	0.02
3	Clay Brick (0.21x0.14 m) Local	0.14
4	Joint Mortar	0.005
5	Interior fine finishing mortar	0.01
6	Acrylic painting for exterior and interior	0.000075
7	Foundation beam	0.15

External- External mortar finished wall W04



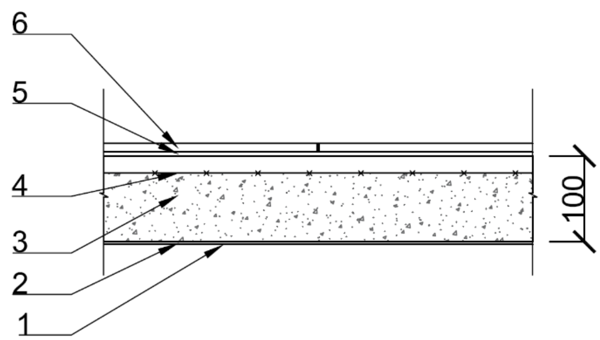
External Wall W04		
Layer	**Description**	**s (m)**
1	Acrylic painting for exterior and interior	0.000075
2	Exterior rough Finishing mortar	0.02
3	Clay Brick (0.21x0.14 m) Local	0.14
4	Joint Mortar	0.005
5	Exterior rough Finishing mortar	0.02
6	Acrylic painting for exterior and interior	0.000075
7	Foundation beam	0.15

Internal partition wall W05



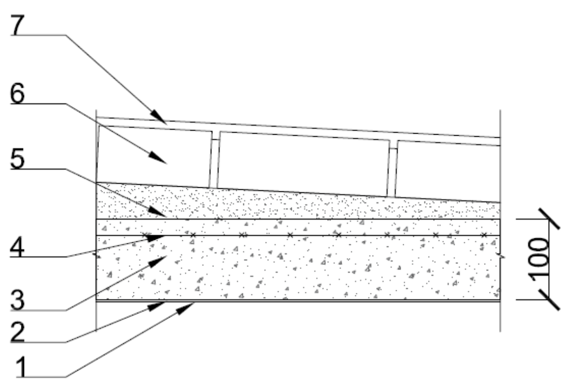
Partition Wall W05		
Layer	**Description**	**s (m)**
1	Acrylic painting for exterior and interior	0.000075
2	Gypsum panel	0.0127
3	Metal studs	0.0635
4	Gypsum panel	0.0127
5	Acrylic painting for exterior and interior	0.000075

Internal floor slab F01



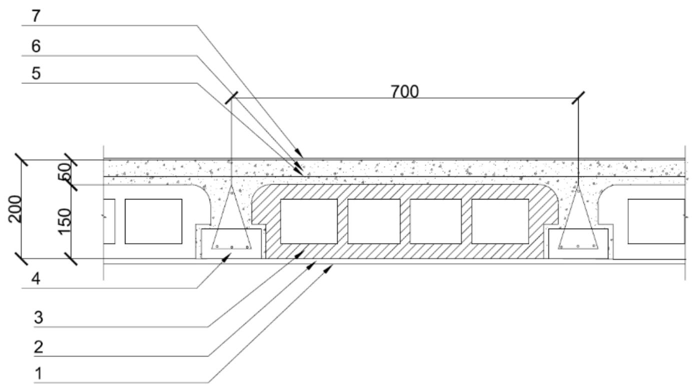
Internal Slab F01		
Layer	**Description**	**s (m)**
1	Acrylic painting for exterior and interior	0.000075
2	Interior fine finishing mortar + Painting	0.01
3	Reinforced concrete slab (f'c= 250 kg/cm^2)	0.1
4	Welded steel mesh 6x6 10/10	0.004
5	Cement based tile adhesive	0.02
6	Granite-cement floor (0.6x0.6 m)	0.01

Plain top roof slab F02



Plain Roof Slab F02		
Layer	**Description**	**s (m)**
1	Acrylic painting for exterior and interior	0.000075
2	Interior fine finishing mortar	0.01
3	Reinforced concrete slab (f'c= 250 kg/cm^2)	0.1
4	Welded steel mesh 6x6 10/10	0.004
5	Sloping material (tepetate)	variable
6	Clay Brick (0.21x0.14 m) Local	0.14
7	Cement Mortar finish	0.005

Sloped roof F03



Sloped Roof F03		
Layer	**Description**	**s (m)**
1	Acrylic painting for exterior and interior	0.000075
2	Interior fine finishing mortar	0.01
3	Cement-sand vault	0.15
4	Pre tensed concrete joist (f'c= 40 kg/cm2)	0.13
5	Welded steel mesh 6x6 10/10	0.004
6	Concrete compression layer (f'c= 250 kg/cm^2)	0.05
7	Acrylic weatherproof layer	0.005

Once organized and studied the constructive components of the project, the next step to be followed consist on get as possible the product supplier information in order to set the component profiles of each material, to then, determine the possible failures derived from the different agents in the immediate environment,

As commented before, the predominance of basic construction systems helps the information management process, as with a reduced quantity of components, it is easier to get each product brochures and facilitates the focusing on the possible issues derived during construction and the use of the building.

Consequently, if can be settled a solid information management system with the basic constructive systems, it can be used as a starting point for future uses at national level, demonstrating that this initiative can apply for different size and complexity projects, always following the same flow of work.

3.3. Location.

To give an idea of the climatic and social environment surrounding the project, it is necessary to set key points referring the project location to the national context of Mexico, in order to determine the conditions or the external agents that can affect the construction at short, medium and long term.

Considering that in such a big country it is possible to find an enormous variety of contexts, it is settled as starting point, to focus on the central region of the country, specifically in the state of Hidalgo, where the main activities are related to the agriculture, commerce and textile industry, thanks to its strategic position between some of the most important developing cities at national level. (i.e. Mexico City is located approximately at a distance of 120 km).

Secondly, as commented in previous stages, CEEH project is located in the municipality of Santiago Tulantepec, placed in the south east sector of the state in the so called "Valle de Tulancingo" economic region. The total municipality population consists of 37,292 inhabitants (2015 INEGI National Survey).

Figure 3.16 Position of the municipality referred to a national and local context (Source: Online research maps)

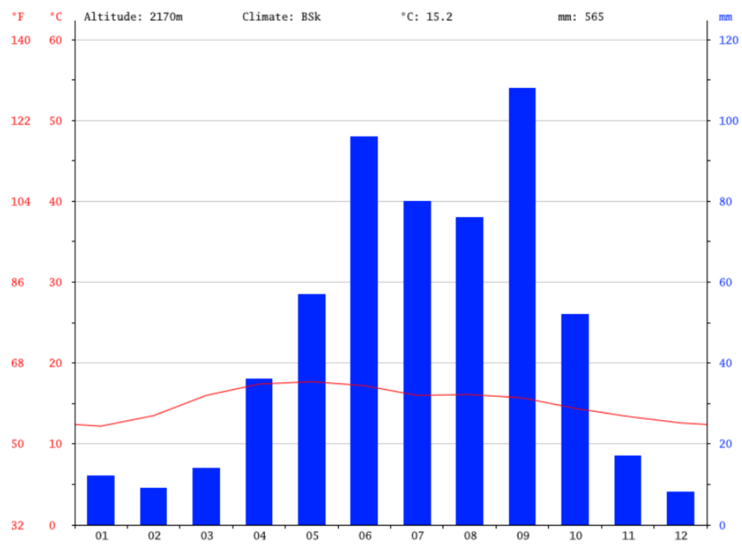
Economically speaking, the main activities developed are based on the agriculture mainly for livestock feeding grains and the textile sector, having a medium size wool fabric factory with local and national sales range, as well as small scale factories providing supplies for the local textile industry. Despite of this, a big part of the active population travels every day to bigger working cities, such as Tulancingo and the state capital Pachuca with the purpose of finding better job opportunities.

Thirdly, now referring to the climatic conditions, it can be considered by its coordinates (20°02'23"N 98°21'27"O) that Santiago Tulantepec is at intertropical zone, having mild climate during the year. With the purpose of give a more specific panorama, the information of the nearest weather station (Tulancingo, 6 km distance) is commented and studied.

Local climate is considered as temperate without dry seasons (Cfb by Köppen Classification), with mild summers and consistent precipitations during the year, mainly affected by the hurricane season that happens from May to October. This is relevant topic to be considered due to the relative proximity to the Gulf of Mexico (200-250 km of distance).

While in winter, is expected to have a decrease of the precipitations and mean temperatures not below 10 °C, even when some days the temperatures can tend to 0 °C in specific winter hours.

Looking at the next figures is possible to have a clearer understanding of the climate behavior during the year at a local level.



Climate data for Tulancingo (Tulancingo Observatory), elevation: 2,181 m or 7,156 ft, 1951–1980 normals, extremes 1951–2000 [hide]													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	29.6 (85.3)	32.0 (89.6)	34.0 (93.2)	35.0 (95.0)	35.4 (95.7)	33.0 (91.4)	29.8 (85.6)	29.4 (84.9)	29.0 (84.2)	37.0 (98.6)	30.6 (87.1)	30.2 (86.4)	37.0 (98.6)
Average high °C (°F)	21.3 (70.3)	22.8 (73.0)	25.8 (78.4)	26.5 (79.7)	26.0 (78.8)	23.8 (74.8)	22.5 (72.5)	22.9 (73.2)	21.6 (70.9)	21.1 (70.0)	21.4 (70.5)	20.7 (69.3)	23.0 (73.4)
Daily mean °C (°F)	12.2 (54.0)	12.9 (55.2)	15.7 (60.3)	16.8 (62.2)	17.2 (63.0)	16.5 (61.7)	15.4 (59.7)	15.6 (60.1)	15.1 (59.2)	13.8 (56.8)	12.8 (55.0)	11.9 (53.4)	14.7 (58.5)
Average low °C (°F)	2.8 (37.0)	3.0 (37.4)	5.7 (42.3)	7.2 (45.0)	7.9 (46.2)	8.3 (46.9)	7.3 (45.1)	7.1 (44.8)	7.5 (45.5)	5.4 (41.7)	4.2 (39.6)	3.1 (37.6)	5.8 (42.4)
Record low °C (°F)	−10.6 (12.9)	−13.8 (7.2)	−7.0 (19.4)	−6.5 (20.3)	−4.0 (24.8)	−3.0 (26.6)	−2.2 (28.0)	−1.7 (28.9)	−5.8 (21.6)	−5.5 (22.1)	−10.0 (14.0)	−8.6 (16.5)	−13.8 (7.2)
Average precipitation mm (inches)	9.7 (0.38)	5.2 (0.20)	11.9 (0.47)	32.4 (1.28)	49.4 (1.94)	94.8 (3.73)	67.4 (2.65)	65.8 (2.59)	114.9 (4.52)	54.3 (2.14)	21.6 (0.85)	7.0 (0.28)	534.4 (21.04)
Average precipitation days (≥ 0.1 mm)	3.07	2.40	3.44	7.03	9.14	13.46	14.74	13.96	16.24	10.18	5.40	3.03	102.09
Average relative humidity (%)	67	64	61	63	66	76	80	78	81	79	74	71	72
Mean monthly sunshine hours	221.8	218.5	227.1	212.7	227.0	192.6	183.4	200.4	150.5	187.0	201.2	199.6	2,421.8
Source #1: Colegio de Postgraduados[7]													
Source #2: SMN[8]													

Figure 3.17 Climate behaviour in Tulancingo (Source: Servicio Meteorológico Nacional SMN)

As can be noticed in the graphics, the tendency of the monthly mean temperatures is between the 10 and 20 °C boundaries, which confirm the predominance of mild temperatures along the year allowing the users to have comfortable indoor temperatures without the need of conditioning systems. While, June and September are characterized by an important increase of rain and additional precautions should be considered to avoid moisture accumulation and water leaking inside the rooms, always monitoring the weatherproof solutions.

In general, once analyzed the context information, is confirmed that the project studied can have a long life cycle in optimal conditions thanks to be in a non-aggressive environment, in which the construction materials can behave in their optimal performance without too much effort, just having a constant inspection and periodic maintenance.

Considering the structure required for the AIM, all the context information serves for the definition of the Organizational Information Requirements, and therefore, influence the scope required for this information process. These OIR may not affect directly the BIM development but the procedures and tasks towards this model.

As commented in the climate section, the rainy season can be crucial in determining the actions to take to maintain the performance of the constructive elements, always controlling any possible issue regarding to moisture and dampness.

In addition, the main economic activities in the municipality are not considered as highly pollutant, avoiding possible problems of carbonation in the external materials as the concrete, or absorption of other emissions that can affect the health of the users.

In the social aspect, knowing that the project is surrounded by a quiet neighborhood with no problems of vandalism or margination and mainly populated by local families, can be considered as to be partially safe. Nevertheless, precautions still need to be taken due to the use of the rooms, considering that activities with children and teenagers will require continuous cleaning of the spaces, but still as part of the normal maintenance that every building must have.

3.4. Site inspection

As stated in the maintenance plan chapter, buildings and its components change performance during its lifecycle, and therefore, during the operative phase under study these changes must be registered in order to do a proper lifecycle assessment and compare the results of these performance level registrations against the designed ones.

For this purpose, ISO 15686-7:2017 standard sets a documentation process in which these reviews can be done and the data obtained from them organized to develop the activities related to the maintenance of the performance levels of each component, for future references these will be called performance surveys.

Performance surveys are based on general and specific documents in which the status of each construction component is declared towards different types of registrations that could be done in the asset. The standard proposes 4 different registration levels according with the information available and the scope pursued by the survey:

a) Level 1 (preliminary): Performance registration of a general character consisting of visual observations combined, if necessary, with simple measurements.

b) Level 2 (regular): Performance registration of a general character, but more exhaustive and detailed than Level 1. It includes examination of supporting data, e.g. drawings, specifications and other documentation. More extensive registrations or measurements should be carried out to establish the construction and performance of the item when required.

c) Level 3 (maintenance-driven): Performance registration of the conditions that exist at the time of a loss of function. Dependent upon the significance of the component or system being considered and the severity of the failure, the requirements of the registration and measurements should be carried out to either Level 1 or Level 2.

d) Level 4 (detailed): Performance registration of a special character that includes only specific items (building elements, construction elements, work sections) or specific problems. Such performance registration implies the application of especially accurate measurement or test methods and, if appropriate, laboratory testing.

Considering that in the study case is counted with the context, delivery phase information and the components analysed and input into the Building Information Model, it can be proceeded to do a physical inspection of the building with the aim of finding possible performance decays on the components and mismatches between the delivery phase information and the current state.

In order to set a mainframe in which the following inspections could be more detailed and scheduled, it is decided to set a Level 1 registration, in which all the constructive elements are identified and detect any possible issued related to its interaction with the context or the operation activities.

As this would be the first documented inspection on the building after its handover, it is seen the opportunity to start working inside the information management process, developing the activity with the support of a general document in which the inspection results can be registered.

Firstly, in order to give a scope to the inspection and the information process, is decided in accordance with the organization to inspect the main closures and the structural elements of the construction, as depending of its results, this registration process could be replicated in the different specialties involving the building.

Once set this agreement, it was proceeded to identify the components under analysis according with the nomenclature proposed during the BIM generation, and the data pretended to obtain from the results of this inspection

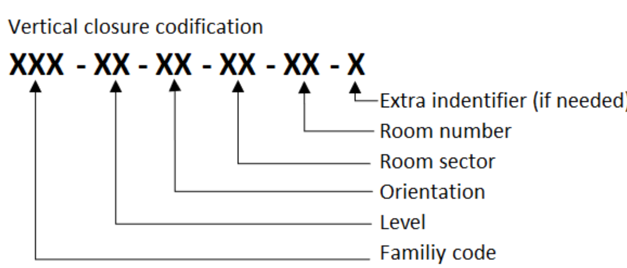
Components subject to inspection					
Vertical closures		Horizontal closures		Structural Elements	
Description	**Family code**	**Description**	**Family code**	**Description**	**Family code**
External glazed brick wall	W01	Internal floor slab	F01	Concrete columns	CCX
External exposed brick wall	W02	Plain top roof slab	F02	Concrete beams	CBX
External- Internal mortar finished wall	W03	Sloped roof	F03	Steel joists	SJX
External- External mortar finished wall	W04				
Internal partition wall	W05				

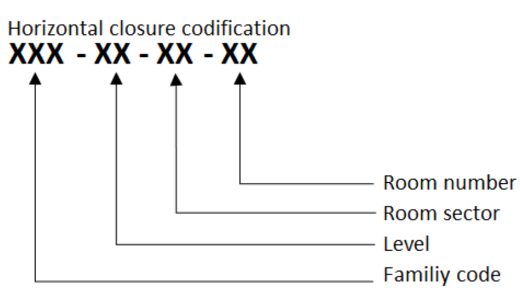
Figure 3.18 Constructive components identification system (Source: CEEH-BIM-XX-03-03-XX Operational phase portfolio)

Having in mind the first documented inspection approach, is agreed with the organization to retrieve the following information requirements:

- Photographic evidence of the building component state or anomaly comparing handover stage vs in use state supported by the delivery phase information. If multiple evidence cases are needed, all must be reflected in the inspection document
- Specific location of the evidence case, for this, a codification system needs to be developed for each component.
- Basic anomaly symptoms recovered from the visual inspection, allowing the user to determine if a more detailed review needs to be performed.

In order to determine the codification of each component inside the project is proposed a format in which could be feasible to identify each component by its orientation and belonging space





Where:

Sectors and rooms schedule			
Sector	**Code**	**Levels**	**Rooms**
Kinder Teaching Room	KT	0, 1	01 to 03
Primary Teaching Room	PT	0, 1, 2	01 to 06
Secondary Teaching Room	ST	2	01 to 03
Informatics Teaching Room	IT	2	01
Vestibule	VB	0, 1, 2	01 to 04
Bathroom	BT	0,1	01 to 03
Principal Office	OF	1	01
Audiovisual Room	AT	1	01
Administration	AD	1	01
Storage	SG	0	01
Stairs	ST	0,1,2	01 to 04
Envelope	EN	0	01 to 06

Orientation Schedule	
Cardinal Point	**Code**
North	N
North East	NE
East	E
South East	SE
South	SE
South West	SW
North west	W

Figure 3.19 Constructive components identification system (Source: CEEH-BIM-XX-03-03-XX Operational phase portfolio)

Once obtained all the requirements and defining the inspection scope, is proposed a general document format in which these basic reviews can be performed and then feed the further data processes inside the AIM and the BIM model.

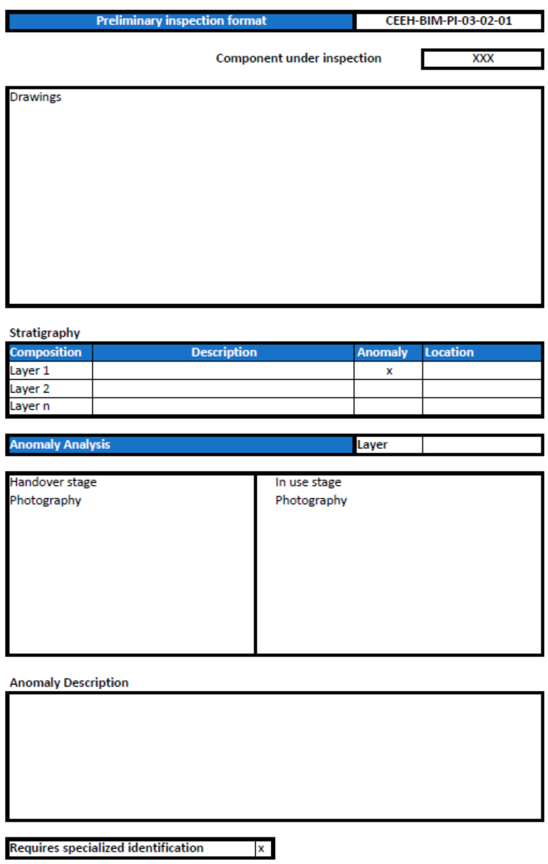
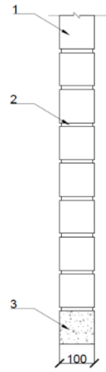


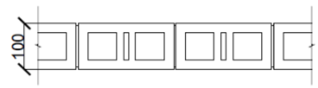
Figure 3.20 Preliminary inspection blank format (Source: CEEH-BIM-XX-03-02-XX: Operational state inspection formats)

Preliminary inspection format	CEEH-BIM-PI-03-02-01

Component under inspection | W01

Drawings





Stratigraphy

Composition	Description	Anomaly	Location
1	Glazed Brick (0.2x0.1 m) Santa Julia	x	W01-00-N-KT-02
2	Joint Mortar		
3	Foundation beam		

Anomaly Analysis	Layer	1

Handover stage

In use stage

Anomaly Description

Adhesive spots in the external surface due to daily operation inside the classroom
Not considered to become a failure

Inspection date	10/01/2020

Preliminary inspection format	CEEH-BIM-PI-03-02-02

Component under inspection W02

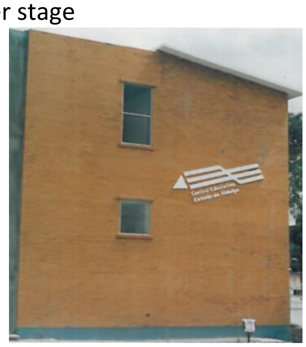
Drawings

Stratigraphy

Composition	Description	Anomaly	Location
1	Extruded Brick (0.29x0.09 m) Santa Julia	x	W02-00-NW-EN-01
2	Joint Mortar		
3	Foundation beam		

Anomaly Analysis	Layer	1

Handover stage



In use stage

Anomaly Description

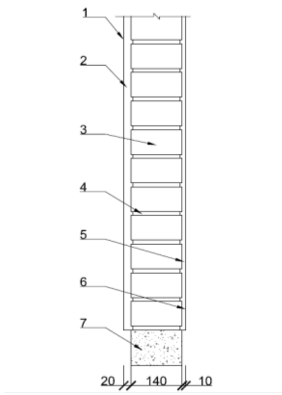
Manifestation of efflorescence spots in the top part of the wall due to evaporation
Surface treatment would be needed

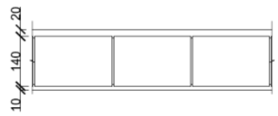
Inspection date	10/01/2020

Preliminary inspection format	CEEH-BIM-PI-03-02-03

Component under inspection W03

Drawings



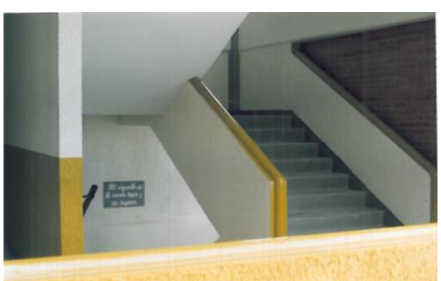


Stratigraphy

Composition	Description	Anomaly	Location
1	Acrylic painting for exterior and interior	x	W03-00-E-SG-01
2	Exterior rough Finishing mortar	x	W03-00-E-SG-01
3	Clay Brick (0.21x0.14 m) Local		
4	Joint Mortar		
5	Interior fine finishing mortar + Painting		
6	Acrylic painting for exterior and interior		
7	Foundation beam		

Anomaly Analysis	Layer	1,2

Handover stage



In use stage

Anomaly Description

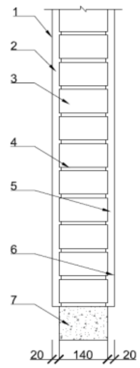
Slight corner cracks due to joint with adjacent wall
Periodic inspection is suggested

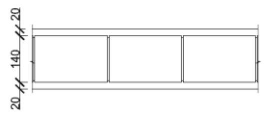
Inspection date	10/01/2020

Preliminary inspection format	CEEH-BIM-PI-03-02-04

Component under inspection W04

Drawings





Stratigraphy

Composition	Description	Anomaly	Location
1	Acrylic painting for exterior and interior	x	W04-02-NW-EN-01
2	Exterior rough Finishing mortar	x	W04-02-NW-EN-01
3	Clay Brick (0.21x0.14 m) Local		
4	Joint Mortar		
5	Exterior rough Finishing mortar		
6	Acrylic painting for exterior and interior		
7	Foundation beam		

Anomaly Analysis	Layer	1,2

Handover stage

In use stage

Anomaly Description

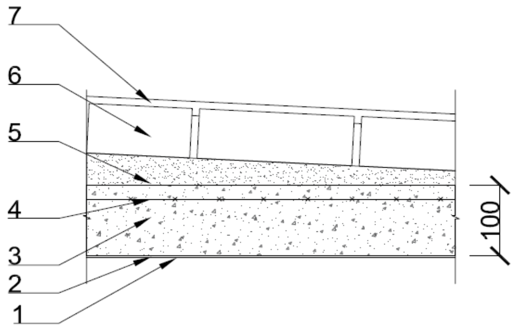
Cracks in the external mortar due to joint with roof slab
According with the architect this failure was existing since the handover stage

Inspection date	10/01/2020

Preliminary inspection format	CEEH-BIM-PI-03-02-05

Component under inspection F02

Drawings



Stratigraphy

Composition	Description	Anomaly	Location
1	Acrylic painting for exterior and interior		
2	Interior fine finishing mortar		
3	Reinforced concrete slab (f'c= 250 kg/cm^2)		
4	Welded steel mesh 6x6 10/10		
5	Sloping material (tepetate)		
6	Clay Brick (0.21x0.14 m) Local		
7	Cement Mortar finish	X	F02-02-XX

Anomaly Analysis	Layer	7

Handover stage	In use stage
Not available	

Anomaly Description

Due to a poor execution during a non registered maintenance, cement mortar intended to work as a weatherproof system failed after a year of service life Finish is falling apart and brick layer 5 is exposed, compromising the service life of the next layers

Inspection date	10/01/2020

As every task implemented in the maintenance plan needs to be verified and approved, is proceeded to test the proposed document analysing the constructive components inside CEEH project and after these inspections are developed, conclusions about the general process will be given.

After analysing the different building components towards the proposed format is possible to say complies with the objectives assessed by the organization as this is a first approach to consider the possible failures of the building at this stage of the lifecycle.

Still the format could be subject of improvements, as more information will be required when the information management process will be more developed as well as the maintenance activities, but as commented in previous sections, the AIM grows and improves continuously with the new information and processes developed.

From the results of inspection, is confirmed the context information with the failures manifested mainly in F02 component, as rain and wind challenged a poor execution system, giving a collapse failure of the external layer in a short time. Action must be taken immediately before the rainy season starts and derives more severe failures.

Respecting the vertical closures, are identified certain symptoms that can cause further failures, but with the inspection performed and the data retrieved is possible to act at time proposing preventive solutions and keep the service life in good performance for the construction.

This task is done as a set of further processes in which all maintenance of the building needs to be performed, and with this basis and the study case information, now it can be developed in a deeper way all the processes accompanying this task, and provide a solid information base in which all the activities are registered.

4. Implementation of BIM execution plan.

Arriving to this stage of the study, is possible to understand the challenges to be faced by the organization and its stakeholders when developing an information management process without a clear and defined structure for all the stages required. In addition, this process requires a complete commitment of all the interested parties when setting the principles and way to work the information that will be generated during the lifecycle of the asset.

At the same time, thanks to the analysis performed in the previous chapters, it can be set a strong information basis in which can be built the required AIM, as now is counted with valuable information in three main stages; Mexican context, standardization and case study.

Nevertheless, before implementing any plan and taking decisions to perform the required tasks, is important to define in which way the information retrieved will be handled and shared by all the interested parties and the targets to be achieved towards this information system.

Therefore, this chapter will deal with the construction of the Asset Information Model (AIM) and the Common Data Environment (CDE) required to allow this flow of information and once set, the maintenance plan can be settled and organized in its different tasks.

As commented in previous chapters, the departure point of this information system would be the requirements and guidelines established by the organization in charge, based on the value objectives purposed for the given asset. Both concepts (value and requirements) need to have agreed objectives in which the information management process will be built.

Using the information basis studied, is possible to build the history of the asset, knowing the reasons behind the decisions taken during the delivery phase and the challenges faced, so the user can have a reference point in which can rely present and future decisions of the processes to be developed.

Not only the information system needs to operate with the information retrieved until now, it is required to have flexibility in order to support future information management processes inside its structure, as is expected that the operative phase of the asset would be challenged by a variety of factors due to the interaction between the constructive elements and the different contexts around them.

For this, it will be used as support the performance survey approach described in ISO 19650-7:2017 in order the assess the remaining lifecycle of the asset under operation, this is in order to develop the activities and resources required to keep it in the best possible performance conditions.

Once defined these tasks, will be developed specific formats in which all the activities can be performed and organized following the structure agreed, and generate information useful for the different purposes of the asset. Moreover, these formats will be tested and improved to allow the user to give the data on an efficient way.

4.1. Goals and uses definition

The first step to set any information management process is to understand the purposes pursued by the organization and the results desired towards the implementation of the mentioned process. Once obtained these requirements is possible to organize a structure in which all the information required can flow and help to comply the value targets set previously.

For this, is possible to rely in the existing standardization that proposes a mainframe in which the information system can be built. As the project is based on the Mexican reality, will be used as reference the NMX-C-527-1-ONNCCE-2017 suggested frame, this considers the information requirements that can be retrievable according with the national organization and technology scope available. At the same time, if some points of this standard are not still developed, international standardization can be used as a support to give strength to this national normalization effort.

Following the content requirements proposed by the standard in figure 2.18 of the section 2.3, goals and uses definition is covered in the points 1 to 6, where the organization and its stakeholders decide the plan implementation, the targets to achieve and its information requirements.

1. Visión general del plan de ejecución
2. Información del Proyecto
3. Personal clave del Proyecto
4. Requerimientos del dueño para el MIC
5. Metas y Usos MIC

1. *Execution plan vision*
2. *Project Information*
3. *Project Key personnel*
4. *Owner requirements for the BIM plan*
5. *BIM uses and targets*
6. *Roles and responsibilities*

Figure 4.1 BEP information requirements related to its goals and uses (Source: Figure 2.18)

To determine all these points, coordination and agreements between all the parts involved are crucial, as the result of these will give clarity to the decision needed to develop the processes and tasks required. All these agreements must be registered and declared in a document which will be the starting point of all the mainframe required by an information management process.

Moreover, according with the needs set by the agreements mentioned before, it must be organized a personnel structure in charge of the development of this information plan, analysing the resources required and the strategies to be applied. All this structure will have a management area which will report the progress of the information plan to the organization and if needed, organize new processes to comply with the value requirements.

For this, is proposed a simplified format in which all the goals and uses definition steps defined by the standardization can be expressed and agreed by all the parties involved (*CEEH-GPR-PI-01-01: Uses and goals for BIM execution plan implementation*), allowing with this the first step towards the creation of the information management process, and initializing the development of the unified information set that will be the base of the further organization of the Asset Information Model. As an illustrative example, the information about the study case will be used to build this document.

Uses and goals for BIM execution plan implementation	CEEH-GPR-PI-01-01

According with the mainframe suggested by NMX-C-527-1-ONNCCE-2017

3.2.1 Execution plan vision

Synthesis of the importance to develop the plan:

CEEH organization, conscious about the importance of keeping their assets in good performance in order to comply with its value concepts, decide to rely on an information management system that can allow all the interested parties take decisions to keep the construction in optimal state, and being able to register and improve the processes required during the operative stage of the building.

Value targets to be complied by the execution plan:

- Social: As education is vital in each worldwide community, if the school is able to operate and bring its services for a longer time, and therefore, more generations, the organization gains value providing such an important service to a specific society.
- Economic: With this building being operative and with acceptable performance along its lifecycle, the investment done by the organization is recovered and the value is increased when the operation could be done without interruptions and the profit is maintained.
- Architecture-constructive: If all the constructive components of an asset are identified and inspected with the aim to work as close as possible to the project expectancies, fewer operative costs could be achieved and the value gain is based on having a building with a high capital gain for the organization.

3.2.2 Project information

Owner	CEEH organization
Project name	Centro Educativo Estado de Hidalgo
Project Address	Calle 1 de abril 56, 43760 Santiago Tulantepec de Lugo Guerrero, Hidalgo, Mexico

	Annex	
Brief description of the project:	Annex	x
Project program:	Annex	x
Project schedule with stages and targets to be achieved:	Annex	x

3.2.3 Project Key Personnel (further information can be found in:)	Annex	x
Owner	CEEH organization	
Project Admin.	CEEH organization	
BIM manager	BMX design	
BIM crew **(to be deifned by BIM management in 3.2.6)**	Annex	x
External personnel (to be defined by the uses and goals)	Annex	x

3.2.4 Owner requirements for the BIM plan

As this is an asset under its operational lifecycle, it is required to develop an information system, in which, is registered on a unified information model, the existing information related to the delivery phase of the project, as well as the information processes to be happened during the remainig lifecycle path of the construction, prioritizing the possibility to perform preventive and unexpected maintenance activities to the constructive elements, guaranteeing a performance able to comply with the value objectives.

3.2.5 Goals and uses for the BIM plan

BIM Goals:

1. Generate a composite information system in which all the delivery phase information of the project is analyzed and the, become the information basis for future decisions regarding the present and future stages of the asset.
2. Generate a BIM model containig the main constructive elements of the asset and define its characteristics towards the exsiting information and physical registrations
3. Once set these previous steps, define the process and tasks needed to allow the best performance of the construction systems, considering possible failures and their fixture process

BIM uses: (could be used as reference Appendix A from NMX-C-527-1-ONNCCE-2017)

A.2 Preventive maintenance program.
Process in which the functionality of a structure and its components are maintained during its operation, with the support of infomation models.

A.3 Building system analysis.
Performance evaluation of the building systems in operation and its comparison against the desired performance.

A.7 Registration model
Development of a "in use" conditions precise model of an existing construction, with all the information that the owner/administrator may require in the future.

3.2.5 Goals and uses for the BIM plan (continues)
BIM uses and goals suitability Thanks to A.7 use, would be possibe to have the necessary information basis of the project, using the project information available and future registration. If using A.3, the constructive components will be analyzed by its different layers and understanding the materials used and its characteristics, having these analysis inside a geometric information container proposed by the BIM model. Then, applying A.2, is possible to determine the main failure causes of the building components, and decide tasks and resources to be applied in order to keep the construction in its best performance

3.2.6 Roles and responsbilities (according wih the uses defined in 3.2.5)	
Use 1	A.7 Registration model
Unit in charge	BIM Management
Unit manager	xx
Personnel required	
Name: BIM modeler **Task description:** With the information retived from the delivery phase, the person in charge will develop the building information model in a 3D software, this is in order to set the different geometric information containers needed to develop the information processes. **Information Requirements:** Information portfolio fo the building delivery phase (plans, photographs, etc) Cross check of the delivery portfolio against current state of the building Creation of a REVIT model in which all the main components are displayed	
Labour hours requested	xx

Use 2	A.3 Building system analysis.
Unit in charge	BIM Management
Unit manager	xx
Personnel required	
Name: BIM component analyst **Task description:** Inside the created BIM, this role will be in charge to inspect and analyse the different constructive layers of each construction component, allowing the BIM manager to take decisions related to the treatment of each component and the scope required. **Information Requirements:** Construction components analysis and layer definition, including material Identification profiles Codification of building components according with the project needs REVIT model updated with the information generated	
Labour hours requested	xx

Use 3	A.2 Preventive maintenance program
Unit in charge	BIM Management
Unit manager	xx
Personnel required	

Name: BIM activity analyst

Task description:

Once defined the tasks the building components and the information system, this role will cover the failure analysis of each component layer and the activities to be developed to procure the maintenance of the construction.

Information Requirements:

Failure profiles for each constructive element

Activity intervention reports

Maintenance activity schedule

REVIT model updated with the information generated

Labour hours requested	xx

Date:

Agreement signature of the interested parties:

Organization	Administration

BIM Management

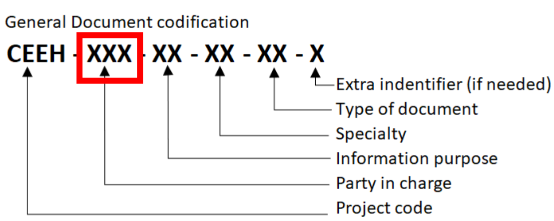
If analysed the developed format, it is considering an organized step process in which the minimum requirements to develop the BIM plan are described and the reasons behind them. This step by step permits the users to display the information required in an easy way, avoiding losses of information due to an ineffective organization.

As every part of the information requirements will need to have its specific documentation, this format is designed with the possibility to add informative annexes completing this document, developing a portfolio where all the information required is stored and referred. In addition, to define the goals and uses related to the creation of the BIM execution plan, is used as guidance the suggested uses specified on NMX-C-527-1-ONNCCE-2017 appendix A, allowing the interoperability between the organizational requirements and the current standardization.

For the purpose of this study, the annexes related to the project information and characteristics are omitted, as they are developed in the Chapter 2 of this document. Nevertheless, the information must be retrieved and stored in this agreement portfolio when would be generated any new BIM execution plan.

As well, this agreement allows to mention the different parties involved in this information process and the responsibilities to be done. For future steps inside the information management process, this is a strong basis to perform the diagrams required to assign the tasks for each event inside the operational stage of the building, giving the structure needed to make a solid unified information model able to deal with all the information processes.

As starting point inside this information processes, this document is named based on a codification system proposed with the objective to define a shared environment and a reading system easy to follow.



Party in charge schedule	
Party involved	**Code**
General purpose	GPR
Organization	ORG
Administration	ADM
BIM Management	BIM
External Source	EXT

Figure 4.2 General document identification system (Source: CEEH-BIM-XX-03-03-XX Operational phase portfolio)

As noted in the scheme above, are organized 6 categories in which every document to be processed and shared can be identified, allowing to each party to have its own code units but inside a unified system that be compatible with every process. In the marked zone is displayed the interested party in charge to generate the documentation, which must match with the points established in the agreement plan generated and the diagrams to be developed.

Therefore, once defined the organizational points and real targets related to the BIM execution plan, it needs to be developed the structure in which these uses and responsibilities can be set and focus to the maintenance plan interesting for this study. In the following section will be analysed the creation of this frame.

4.2. Diagrams, structure and EIR definition.

As commented in section 2.5, the main trigger event related to this study will be maintenance plan to be executed in the CEEH project, considering different planned and unplanned appointments that would generate information inside the composite system. Now, with the definition of the goals and uses of the BIM plan done, this trigger event is joined by two additional ones (building system analysis and registration model) that will support the maintenance plan and the activities executed inside it.

Therefore, is needed to define a diagram in which all the trigger events mentioned before can interact and develop the appointments required for the maintenance plan. With the purpose to make this interaction happen, will be analyzed the information retrieved in the CEEH-GPR-PI-01-01 document, in which are set the basic requirements of the BIM execution plan.

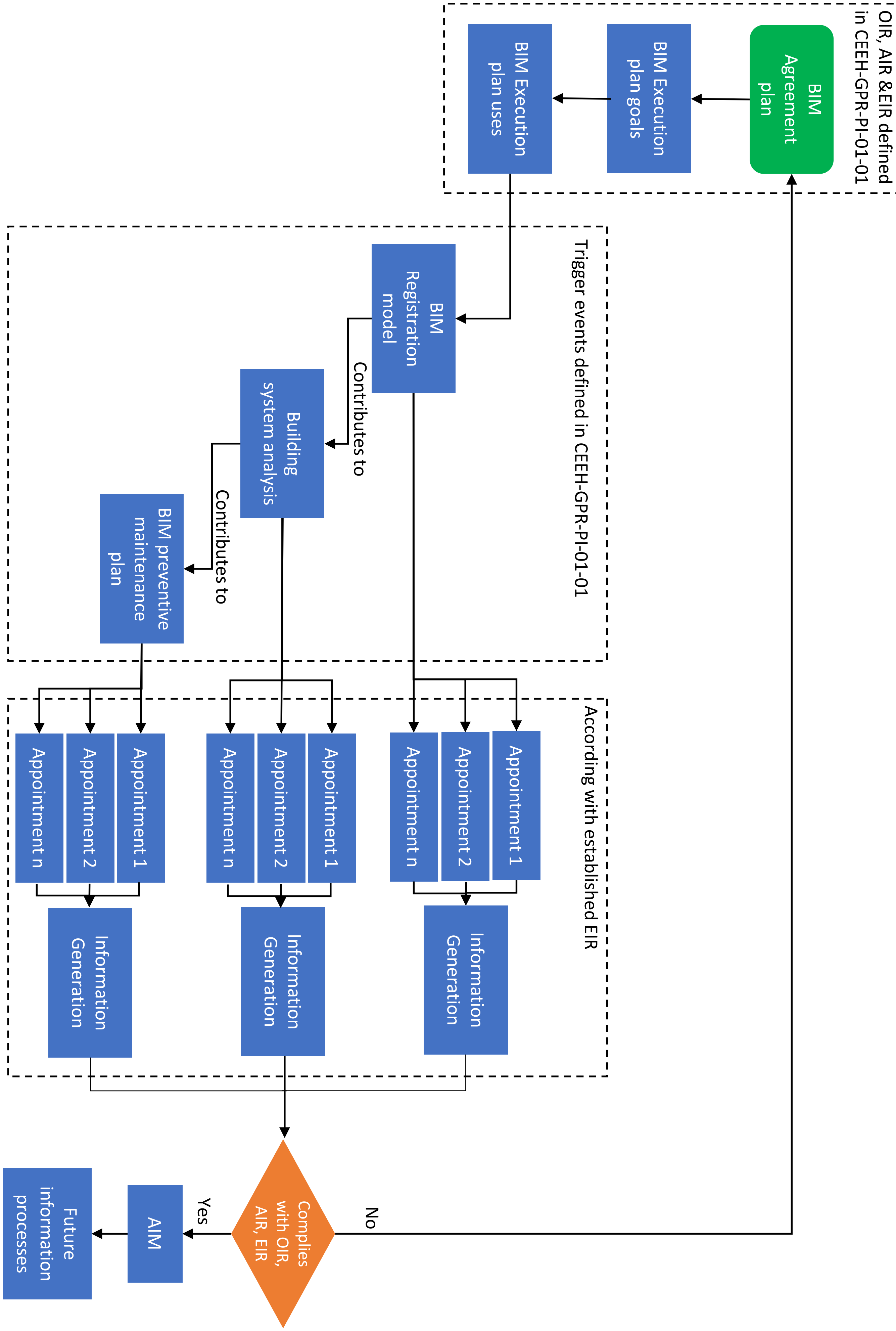
Considering the scope proposed in ISO/DIS 19650:3:2019, is important to set the parallelism in the terms applied between this standard and the Mexican standardization with the objective to have a more clear understanding about the structure needed to rule the BIM execution plan.

In CEEH-GPR-PI-01-01 agreement plan is included the organizational scope related to the BIM plan implementation and the demands to be covered by this, defined by the BIM goals. Looking ISO terms these requirements become the Organizational Information Requirements (OIR), to be fulfilled by the BIM uses proposed in NMX standardization, which also are parallel with the Asset Information Requirements (AIR) that cover the needs of the OIR.

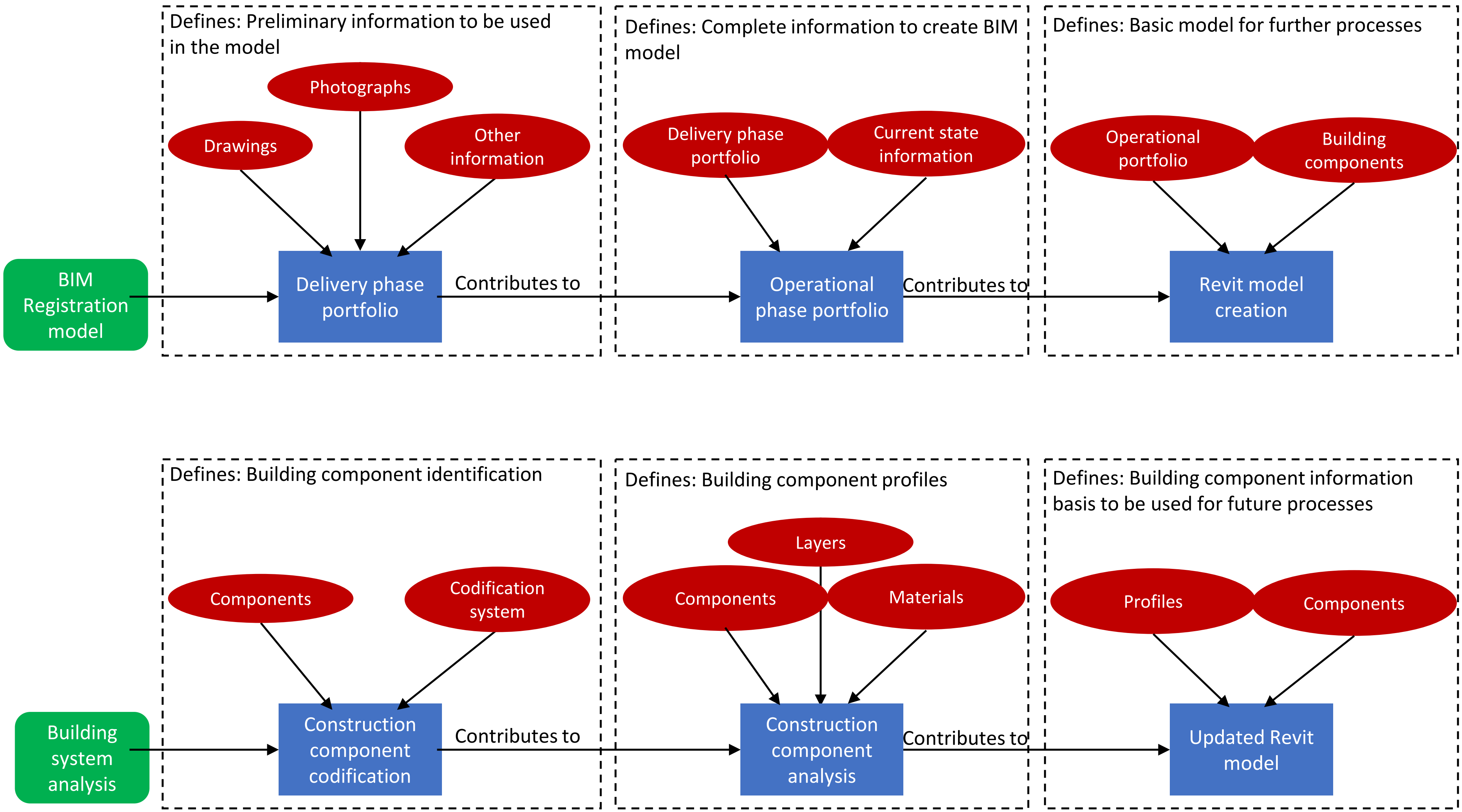
At the same time, according with each trigger event, are designated different Exchange Information requirements (EIR), required to deliver the information processed in each stage. All these EIR must be suitable for the interoperability between all the trigger events, in this way, all the information can flow inside the composite information system having the same information platforms.

Consequently, now is possible to develop a general diagram with the points retrieved during the agreement stage, considering the different trigger events and information requirements supporting the main objective of the maintenance plan, developing information plans which must be reviewed against OIR, AIR and EIR of the project. Once approved, they can form the Asset Information Model (AIM) and generate all the information required for future processes.

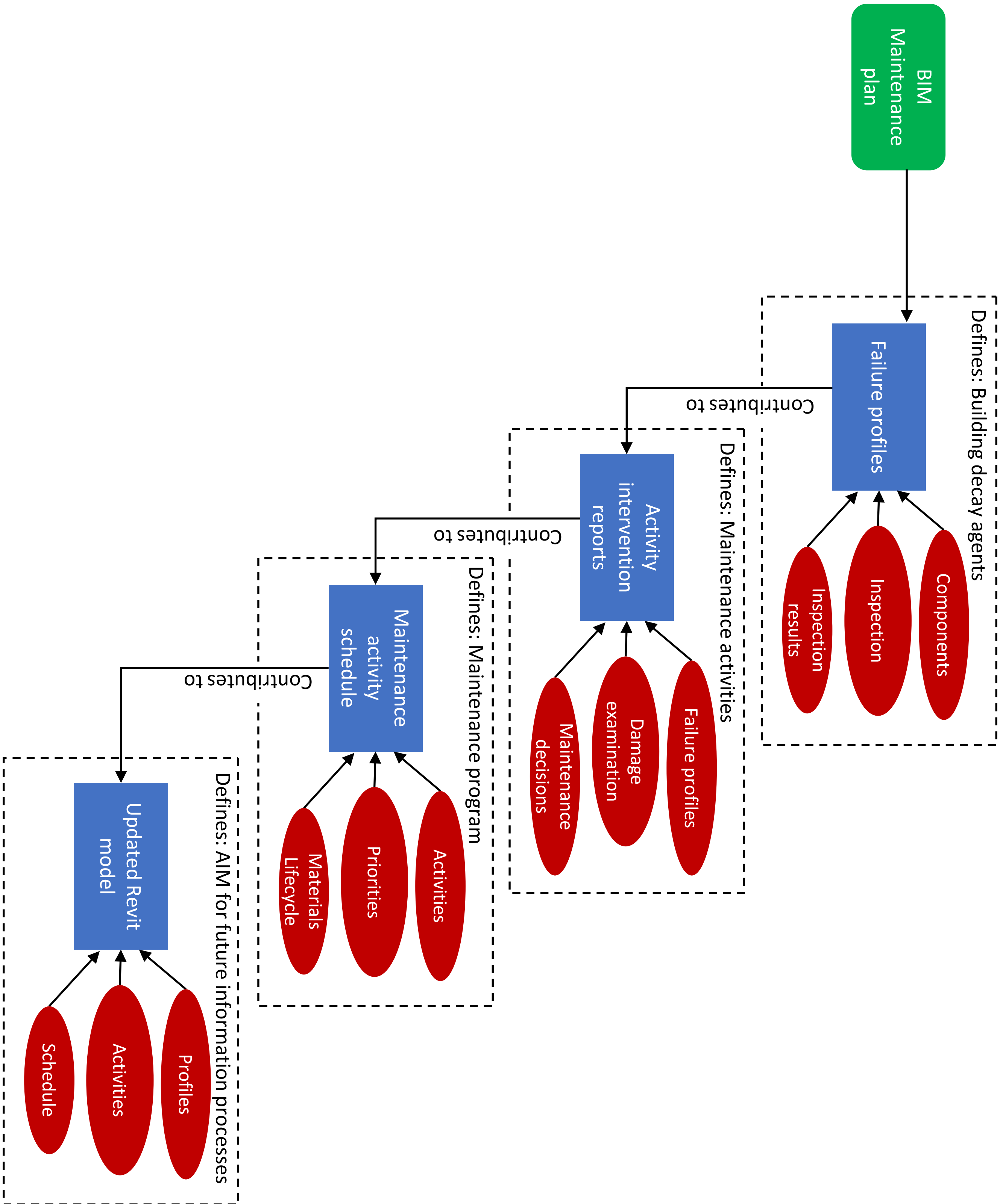
In addition, will be developed the specific diagrams for each trigger event, considering a sequence in which the compliance of one initial trigger event contributes to the compliance of the next one, allowing the maintenance plan have a solid information model in which all the processes and decisions become easy to develop and execute. Finally, all the main activities defined to cover the specific appointments are provided with a definition objective, so can be easy to measure and track the progress of this activities against BIM execution plan expectations.



CEEH-BIM-PI-01-01: BIM Execution plan general diagram

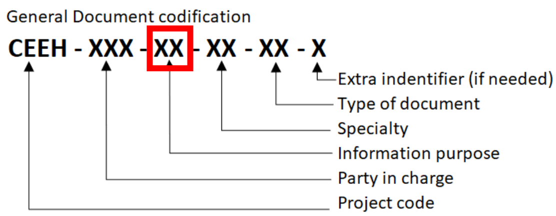


CEEH-BIM-PI-01-02: Specific events BIM execution plan diagram


BIM Maintenance plan
Failure profiles
Defines: Building decay agents
Inspection results
Inspection
Components
Contributes to
Activity intervention reports
Defines: Maintenance activities
Maintenance decisions
Damage examination
Failure profiles
Contributes to
Maintenance activity schedule
Defines: Maintenance program
Materials Lifecycle
Priorities
Activities
Contributes to
Updated Revit model
Defines: AIM for future information processes
Schedule
Activities
Profiles

Now, with the diagrams and tasks defined, is necessary to set how the information will be identified based on the progress of each task and its related documentation, passing through different approval stages to then be published inside the AIM as official information.

At this point, the Common Data Environment (CDE) can be built considering the developed document codification system towards the information purpose code space, setting the different information stages decided to implement during the information generation.



Information purpose	
Purpose	**Code**
Preliminary information	PI
Verified information	VI
Developing information	DI
For review	RV
Published	PB
Archive	AR

Figure 4.3 CDE stages inside the document identification system (Source: CEEH-BIM-XX-03-03-XX Operational phase portfolio)

In addition, are explained the different information purposes to be achieved by each stage:

- Preliminary information: First information retrieved by different sources (existing plans, documents, photographs, contracts) to be analysed and selected to develop the documentation required.
- Verified information: Once passed the preliminary stage, this information is organized and treated according with the documents to be generated.
- Developing information: Documents in charge of the different task teams that are in generation process, still considered as user information.
- For review: Next level of information, where the information is now property of the task team and to be reviewed and approved by the lead in charge.
- Published: With the approval of the task team, this information passes inside of the Asset Information Model (AIM), to be shared and commented with the different parties involved in the project.
- Archive: Inside the AIM, this space covers the end of a specific information process or reference of previous tasks developed to be considered in future processes.

Thanks to the implementation of these simple steps, the information retrieved and generated can be categorized and treated in an effective way, firstly inside the task teams and worked at small scale, to then pass to a shared system where all the users can access to the information and improve their own processes in a collaborative environment.

At the same time, this helps to avoid information voids in the system, as the codification allows to trace previous processes and decisions made at a certain point of the building lifecycle, understanding the reasons and developing the new decision with a reliable knowledge basis.

Once defined the diagrams and the CDE ruling the information system, is possible to think in a more detailed scope, defining each one of the tasks and processes to be done in order to achieve the final BIM maintenance plan required by the organization, following the sequence developed until now and comparing step by step the achievements done and give strength to the future processes.

4.3. Asset Information Protocol and Reference Information compilation

Following the information sequence obtained until now following the methodology of the national standardization, the next step into this information management process will be to define the outputs to be generated and the hierarchy needed to review and approve these information processes to create the AIM.

With the purpose to give continuity to the parallelisms between Mexican and international standardization, will be studied both cases with the aim to define a process suitable and easy to follow. In the national frame the information process required to organize the different outputs and the way to be shared is referred in steps 3.2.8 & 3.2.9 of the NMX-C-527-1-ONNCCE-2017.

8. Intercambios de Información	*8. Information exchanges*
9. Estrategia de colaboración	*9. Collaboration strategies*

Figure 4.4 BEP information requirements related to its outputs and collaboration (Source: Figure 2.18)

In these categories, are displayed the main requirements that allow the collaboration between the different processes and the teams involved in each task, in accordance with the BIM goals and uses defined in the previous information agreement. All this structure is parallel to the definition of the Asset Information Protocol proposed in ISO/DIS 19650:3:2019, in which is also explained the need to the creation of a list of information exchanges explaining the information needs and the platforms agreed to enhance the information flow between the different task teams and their superior structures.

As the collaborative working environment requires agreements between the different parts involved in the project, is proposed a format where all these information processes are listed and defined the hierarchy required to be reviewed and approved. Inside the proposed document is decided to input the following information categories.

- Codification: Identification assigned inside the information management system.
- Activity name: Activity definition inside the information management system.
- Information Generator: Member of the BIM plan structure in charge to develop the information and report the progress to their superior structures.
- Information reviewer/approver: Responsible to check the information generator and emit comments until the process is ready to be published.
- Information requirements: Information needed to be retrieved for external sources or from previously generated documentation to allow the interoperability.
- Software: Formats and outputs required for the information flow.

In the following pages is displayed the proposed format (*CEEH-BIM-PI-02-01: Asset Information Protocol*) considering the structure defined above and establishing a reference system between the different documents that feed the information required to develop every stage of this document.

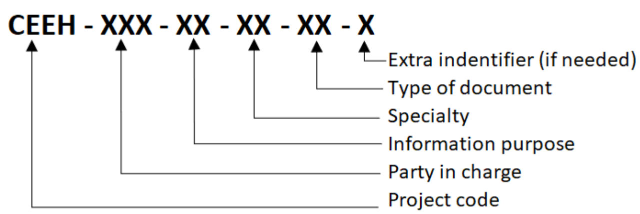
Asset Information Protocol	CEEH-BIM-PI-02-01

According with the points 3.2.8 & 3.2.9 of the execution plan suggested by NMX-C-527-1-ONNCCE-2017

Objective:
Define the information exchanges required for the BIM diagrams and set the documentation to be generated with its respective resources and responsibilities.

Reference documents:
CEEH-GPR-PI-01-01: Uses and goals for BIM execution plan implementation
CEEH-BIM-PI-01-01: BIM execution plan general diagram
CEEH-BIM-PI-01-02: Specific events BIM execution plan diagram

General Document codification



BIM specialty schedule	
Specialty	**Code**
Diagrams	01
Plans and protocoles	02
BIM registration model	03
Building component analysis	04
BIM Maintenance plan	05
Others	06

Party in charge schedule	
Party involved	**Code**
General purpose	GPR
Organization	ORG
Administration	ADM
BIM Management	BIM
External Source	EXT

Responsible schedule	
Responsible	**Code**
Organization	ORG
Administration	ADM
BIM Manager	BMG
Task team lead	TTL
Task team crew	TTC

	Code	Activity name	Generator	Reviewer	Information requirements	Software
BIM registration model	CEEH-BIM-XX-03-01-XX	Delivery phase portfolio	TTC	TTL, BMG	Photographs, delivery phase drawings and specifications	PDF creator
	CEEH-BIM-XX-03-02-XX	Operational state inspection formats	TTC	TTL,BMG	Delivery phase portfolio, inspection results	Excel
	CEEH-BIM-XX-03-03-XX	Operational phase portfolio	TTC	TTL, BMG	Delivery phase portfolio, operational state inspection,	PDF creator
	CEEH-BIM-XX-03-04-XX	Registration model	TTC	TTL, BMG, ORG	Delivery phase portfolio, operational phase portfolio	Autodesk Revit
Building system analysis	CEEH-BIM-XX-04-01-XX	Construction component codification	TTC	TTL, BMG	Registration model	Autodesk Revit, Excel
	CEEH-BIM-XX-04-02-XX	Building component profiles	TTC	TTL, BMG	Building components, layers and material profiles	Autodesk Revit, Excel and PDF creator
	CEEH-BIM-XX-04-03-XX	Construction components model	TTC	TTL, BMG, ORG	Registration model, building component profiles and construction component codification	Autodesk Revit, Excel
BIM maintenance plan	CEEH-BIM-XX-05-01-XX	Maintenance assessment protocol	BMG	ORG	Construction components model	Excel
	CEEH-BIM-XX-05-02-XX	Failure profiles	TTC	TTL, BMG	Building component profiles, inspection format results	Excel
	CEEH-BIM-XX-05-03-XX	Activity intevention reports	TTC	TTL, BMG	Failure profiles, inspection results	Excel
	CEEH-BIM-XX-05-04-XX	Maintenance Activity Schedule	TTC	TTL, BMG	Activity intervention reports, building component profiles	MS Project
	CEEH-BIM-XX-05-05-XX	Maintenance model	TTC	TTL, BMG, ORG	Failure profiles, activity intervention reports, maintenance activity schedule	Autodesk Revit, Excel

With the information protocol format developed and reviewed, now is clear the documentation process to be developed in order to build the maintenance plan pursued by this study, interconnecting the different information processes needed at each stage and setting measurable and quantifiable information goals.

This step is fundamental at the moment to define the magnitude of the execution plan, as now is possible to assign the different requirements and resources to the tasks teams in charge, and respectively, the task teams will assign the responsibilities between their crew.

As in every information process, communication between the different task teams and interested parties is essential to follow the progress of each information stage, notifying any issue and allowing the collaboration of all the parties in order to improve the process and arrive to better results.

Even though is explained in this chapter all the structure required to arrive to the Asset Information Model (AIM), some information steps were generated before the analysis of this organized plan of work, considering that the information retrieved will help to develop the documentation required for the execution plan

This information is referred to the study case developed in chapter 2, where the main information related to the CEEH project is retrieved and started to be organized inside the registration model, where the different plans and constructive elements were developed until now, as well as the preliminary inspection formats to know the current state of the construction components and have the information basis required to develop the maintenance plan.

Not only technical information was retrieved in this study case analysis, but at the same time the organizational aims and requirements related the asset and the different contexts in which the construction will be exposed and their possible defective performance factors. Part of this information is now reflected in the agreements and plans developed in this chapter.

Once inside the AIM, this delivery phase information can be stored in the appropriate information containers proposed by the CDE developed in the previous section, and following the agreed codification system developed with the documentation structure, so every member of the task teams that require any source of information can access to it on an easy way and avoiding information voids or document confusions.

Currently, with the information and organization efforts done until now, is possible to convert this sequence of processes into the AIM, analysing the missing requirements to create it and how the information retrieved until now can support the AIM mainframe to have the required unified information system able to deal with present and future information processes.

4.4. Asset Information Model (AIM) creation.

Keeping in mind the concept of the AIM to be the unified source of information between all the interested parties and the processes needed to keep an asset in good performance conditions, is fundamental that the principles in which will be based are defined since the very early stages of the project.

Once defined these principles, the OIR, AIR and EIR will give shape to the requirements and rules in which the AIM will be operating, and therefore, being able to evolve and improve processes according with the requirements previously mentioned and the changing needs of the project. This means that not only the AIM should work for pre-stablished conditions planned with the asset portfolio retrieved, but also being operative for reactive information generation due to the nature of the appointments that the asset will have during its operational life.

In the previous definition stages of this chapter, was developed the mainframe in which the maintenance plan is desired to work, towards a documentation system which enables to understand the information requirements and the outputs requested by the different parties and its way to be shared. This interaction between the different stages and the documentation developed until now can be seen with the help of the following diagram of BSI PAS 1192-3:2014 and the formats developed.

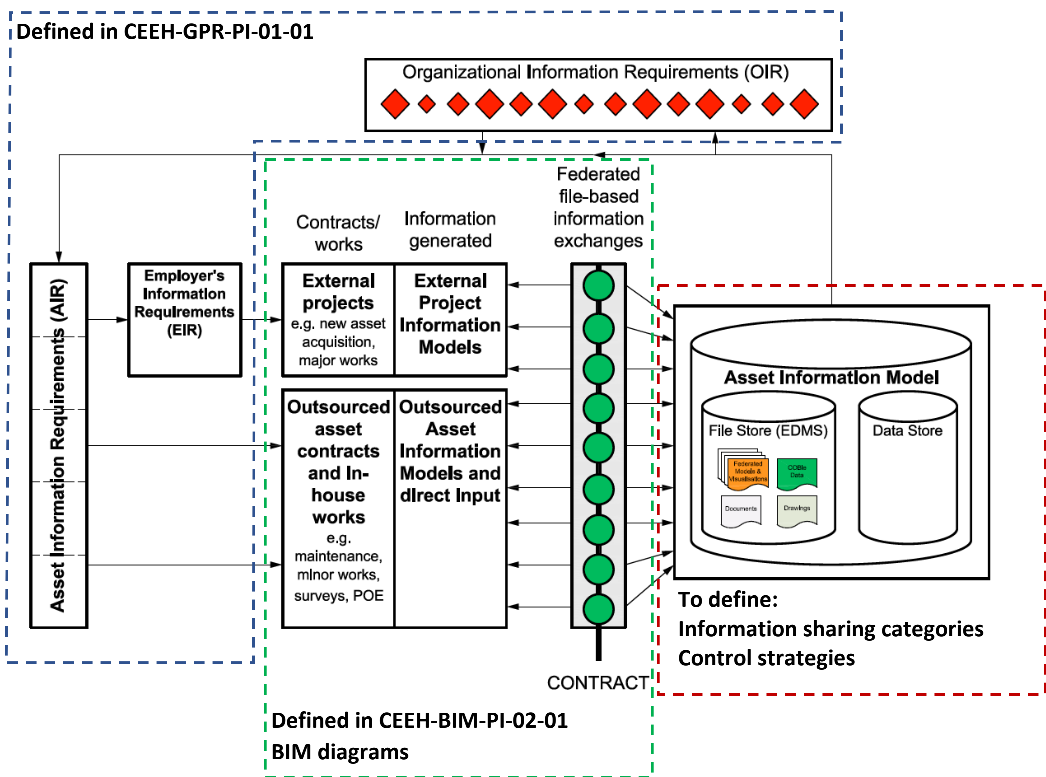


Figure 4.5 AIM interaction diagram with the suggested document system (Source: BSI PAS 1192-3:2014)

As noted in the figure 4.5, the AIM is not only an information reservoir for all the processes, but also need to have specific rules and control systems in which the information can flow and avoiding useless practices like duplicating information or having various versions of certain documentation, this is why a correct management and maintenance of this AIM must be provided and monitored at every stage of the operational phase of the asset, leaving a structured information base for future processes.

Therefore, will be analysed two main function requirements for the AIM, starting with the categories in which the information will flow inside the AIM and its main features, as well as a simple control system in which the information generated will be registered and set a trace to be followed in future information management processes and audits, required to keep the AIM in the desired functional state.

Firstly, is important to determine the information levels in which the information will be treated and the ownership of each stage, this means that in every level the information processed will have different users involved, until the purposes of this process are complied according with the OIR, AIR and EIR and the outputs are reliable and ready to be shared into the AIM.

Taking as base the categories proposed to be used in CDE, is possible to define the different categories in which the information can be shared and the ownership, defining three main sharing groups to be implemented for all the information processes.

Information purpose		
	Purpose	**Code**
Single user property	Preliminary information	PI
	Verified information	VI
Shared inside TT's	Developing information	DI
	For review	RV
Approved and inside the AIM	Published	PB
	Archive	AR

Figure 4.6 Sharing categories inside the AIM (Source: CEEH-BIM-XX-03-03-XX Operational phase portfolio)

This helps to the AIM to have only information that has passed the single user and shared categories, establishing a sequence of reviews and corrections before these information processes can be considered reliable and ready to use in a collaborative working environment, and keeping unfinished processes into a safe zone inside the task team spaces until these are ready to be shared.

In addition, is needed a control system in which all the main stages related to an information process or document, can be recorded and set the desired progress trace for future processes or audits. For this second part of the AIM to be analysed, is proposed an document track review format *(CEEH-BIM-PI-02-02: Document control and comments review)*, including the main parts involved in the information generation and the possibility to add comments to each stage, giving also an effective communication system between all the interested parties, crucial at the moment to take decisions about the information treatment and the improvements required to make the processes even better. This format is included in the following page.

Document control and comments review	CEEH-BIM-PI-02-02

User initials (team)	Date	Work status	Comment
XXX (TTC 1)	18/03/2020	RV	V0.0 ready for TTL comments
XXX (TTL 1)	20/03/2020	RV	V0.0 reviewed and commented, corrections to be done, see comments in XXXXXXXXXX
XXX (TTL 1) **XXX (BMG)**	21/03/2020	PB	V1.0 Fomat approved by TTL and BMG, ready to be applied inside the AIM.
XXX (BMG)	05/06/2020	AR	Due to new information requirements, V1.0 is archived and V1.1 is sent to information generation process to its respective TTC

Color schedule:

(yellow)	Document or process generation and review
(orange)	Document or process released
(dark gold)	Major change requiring new process version

Responsible schedule	
Responsible	**Code**
Organization	ORG
Administration	ADM
BIM Manager	BMG
Task team lead	TTL
Task team crew	TTC

Information purpose	
Purpose	**Code**
Preliminary information	PI
Verified information	VI
Developing information	DI
For review	RV
Published	PB
Archive	AR

In the example comments developed in the format, is set the a simple case since the generation of the information, passing through a revision, approval and use, until this process need a re-structure or a major improvement developing a new version of the process, keeping the information generation cycle always registered and easy to follow.

This format is intended to be attached inside every information generation process (documentation), allowing that every step developed inside the citated document is correctly reported and the users involved would be able to solve the issues during the development of the information exchange.

Thanks to these efforts, the AIM is supported and ready to work with the information retrieved until now, categorizing the information and allowing the different parties to take actions in the information processes that they require, following the hierarchy and structure inside their respective task team or interested party.

Having this structure operative and correctly managed, will allow the organization to have a solid infrastructure able to face the different stages of the operative phase of the asset, even if the administration or the BIM manager roles need to be changed, the AIM could remain stable and the required information of the asset is kept safe for the process that this will require.

In addition, the commitment necessary from all the interested parties to keep the AIM in good functioning can be encouraged providing the correct tools for every party to make their own processes and demonstrate that following an organized structure and a correct information categorization not only improves the work development inside their crew, but also, improving their processes contribute to the general improvement of all the interested parties work development, and therefore, to comply in a better way the value requirements set by the organization.

Consequently, having developed every single step required to define a BIM execution plan, finally this study has enough information resources to develop the desired maintenance plan process, and generate the documentation established in these previous steps to take further actions and decisions in order to keep the existing study case in the best performance possible, considering that the constructive elements have manifested some failures registered now, and documented processes are needed to face these challenges.

4.5. BIM maintenance plan development.

Keeping an asset in the best performance conditions requires a deep comprehension of the components pretended to be maintained towards an effective information system that will help the maintenance performer to take better decisions and implement information based actions for he different events that the asset will have.

This information system and its resources will depend directly on the decisions made since the organizational stages of the project, and bringing these decisions in form of requirements to be fulfilled by the processes implemented by the different task teams in charge of the information management process.

Having developed in the previous sections the mainframe in which will be developed the information system and providing a structured way of work compatible with the different parties, the maintenance plan needed to fill the agreement plan requirements has enough resources to be planned and design the actions and formats that will give shape to the works required to keep the asset in good conditions, relying in the information basis retrieved and being able to transmit the results inside the AIM structure.

As commented during the inspection performance in section 3.4 of this study, there will be used the standardization mainframe proposed by ISO 15686-7:2017, mainly focused on the performance surveys approach. This will help to define in a more specific way the requirements and the guidelines in which the maintenance plan will work and the processes to be implemented during the creation and operation of this plan.

In this standard is organized a set of definition stages which the performance survey must fulfil and implement the execution plan, starting with the purpose of the survey and the main components of the asset to be analysed, as well as the criteria to evaluate its performance. This will help the BIM management team to delimitate the goals to be achieved in a realistic and quantifiable way, assigning the proper resources to the different tasks, and developing the sequence of work towards the execution diagrams required.

Moreover, this survey will contribute to improve the recently generated information basis in form of general documents inside the AIM, transforming it in specific documentation as proposed in the mentioned standard to comply with the desired targets and generate the new information obtained for each process inside the citated AIM.

Thus, following the approach of generating defining documentation for each section, it is proposed a document *(CEEH-BIM-PI-05-01-01: Maintenance information protocol)*, in which all the requirements and statements to be followed by the maintenance plan are declared, as well as an activity diagram showing the different information processes to be generated and their correlation, giving a sequenced way of work for all the appointments to be happened in the operative life of the asset.

Maintenance assessment protocol	CEEH-BIM-PI-05-01-01

According with the mainframe suggested by ISO 15686-7:2017

Objective:
Define the purpose of the BIM execution plan and the scope to be analyzed during the creation of this plan

Reference documents:
CEEH-GPR-PI-01-01: Uses and goals for BIM execution plan implementation
CEEH-BIM-PI-01-01: BIM execution plan general diagram
CEEH-BIM-PI-01-02: Specific events BIM execution plan diagram
CEEH-BIM-PI-02-01: Asset Information Protocol

1. Task definition

Purpose of the plan:
Provide a set of information and documentation related to the maintenance of the constructive elements of the building, in order to develop the different tasks inside the building maintenance plan and organize the different activities.

Extents and costs:
With the purpose of developing the maitenance master plan, is decided to analyse the main building components based on the field inspection executed in January 2020. This process could be enriched in further stages with all the components inside the building

Vertical closures:
W01, W02, W03, W04, W05
Horizontal closures:
F01, F02, F03

Costs to be developed in further stages in accordance with the organization and BIM management.

2. Planning

Meetings with the different parties to define phase target

a) Operational state report meeting
b) Maintenance agreement meeting
c) Results report meeting

2. Planning (continues)

General documentation to be used according with CEEH-BIM-PI-02-01 :

CEEH-BIM-XX-03-01-XX: Delivery phase portfolio
CEEH-BIM-XX-03-02-XX: Operational phase inspection formats
CEEH-BIM-XX-04-01-XX: Construction component codification
CEEH-BIM-XX-04-03-XX: Construction components model

Specific documentation to be generated according with CEEH-BIM-PI-02-01 :

CEEH-BIM-XX-04-02-XX: Building component profiles
CEEH-BIM-XX-05-02-XX: Failure profiles
CEEH-BIM-XX-05-03-XX: Activity intervention reports
CEEH-BIM-XX-05-04-01: Maintenance activity schedule
CEEH-BIM-XX-05-04-02: Reactive maintenance activity schedule
CEEH-BIM-XX-05-05-XX: Maintenance activity portfolio
CEEH-BIM-XX-05-06-XX: Maintenance activity report
CEEH-BIM-XX-05-07-XX: Maintenance model

Plan diagrams to be executed:
See Annex A & B.

3. Examination

Phase documentation:

CEEH-BIM-XX-04-02-XX: Building component profiles
CEEH-BIM-XX-05-02-XX: Detailed inspection formats

Phase description:
Towards the identification of the main constructive elements to be analysed, is described the current state of the building, pointing the main issues found during the inspection and report the possible causes of the malfunction

4. Evaluation

Phase description:
Following the examination stage, the next step is to evaluate the issues reported and define the decisions and activities related to the optimal performace or the construction, as well as plan the maintenance interventions based on the element lifecycle and damage evaluation.

4. Evaluation (continues)

Phase documentation:

CEEH-BIM-XX-05-02-XX: Failure profiles
CEEH-BIM-XX-05-03-XX: Activity intervention reports
CEEH-BIM-XX-05-04-01: Maintenance activity schedule
CEEH-BIM-XX-05-04-02: Reactive maintenance activity schedule

5. Reporting

Phase description:
Once the maintenance activity planning is approved, is proceeded to execute the different tasks according with the reactive and preventive schedules, coordinating action with the different interested parties in order to avoid operative closures or interferences. Later on, is reported the result and handover of the construction after maintenance to its comment or approval. Once this process is finished, is archived inside the AIM.

Phase documentation:

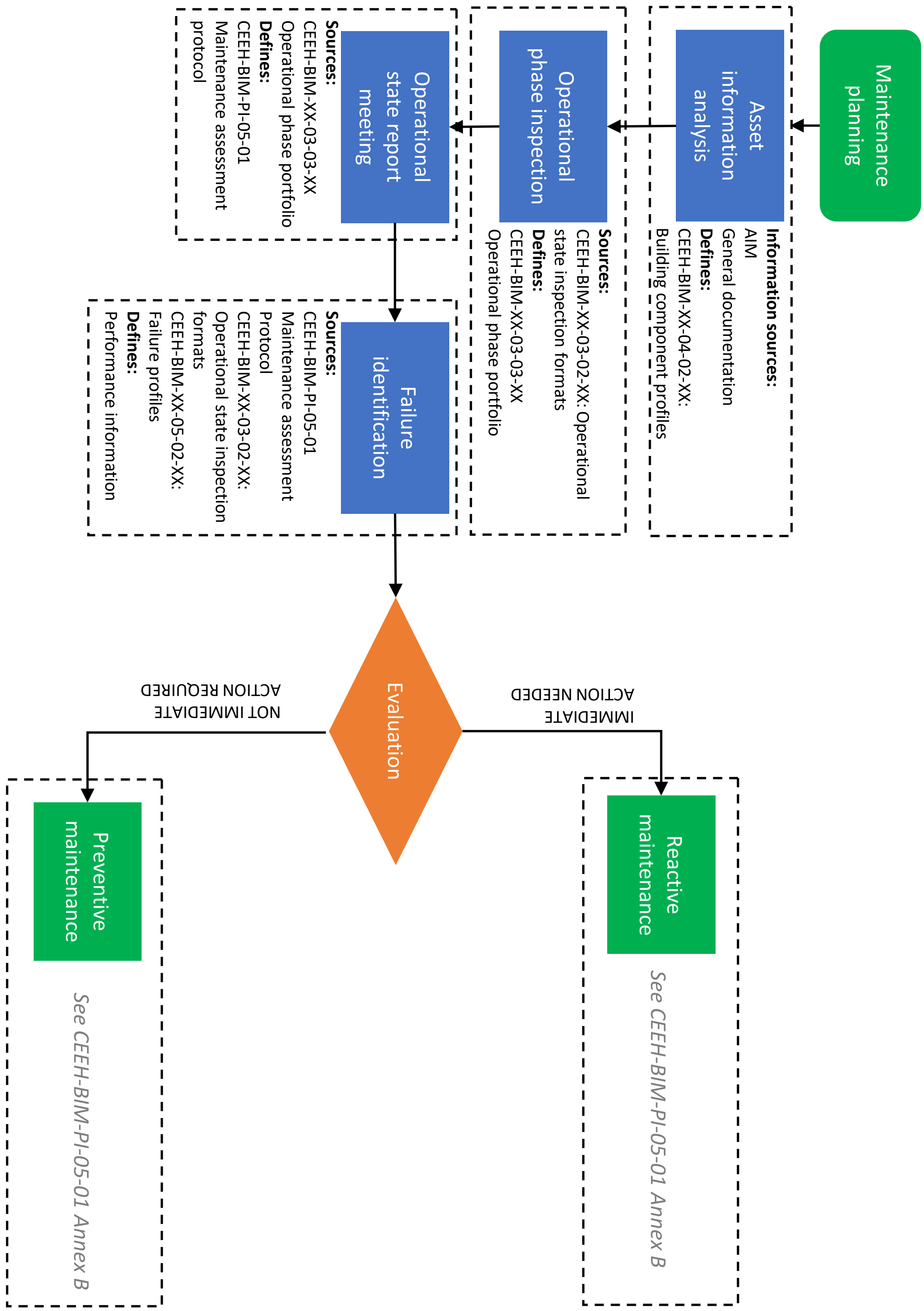
CEEH-BIM-XX-05-05-XX: Maintenance activity portfolio
CEEH-BIM-XX-05-06-XX: Maintenance activity report
CEEH-BIM-XX-05-07-XX: Maintenance model

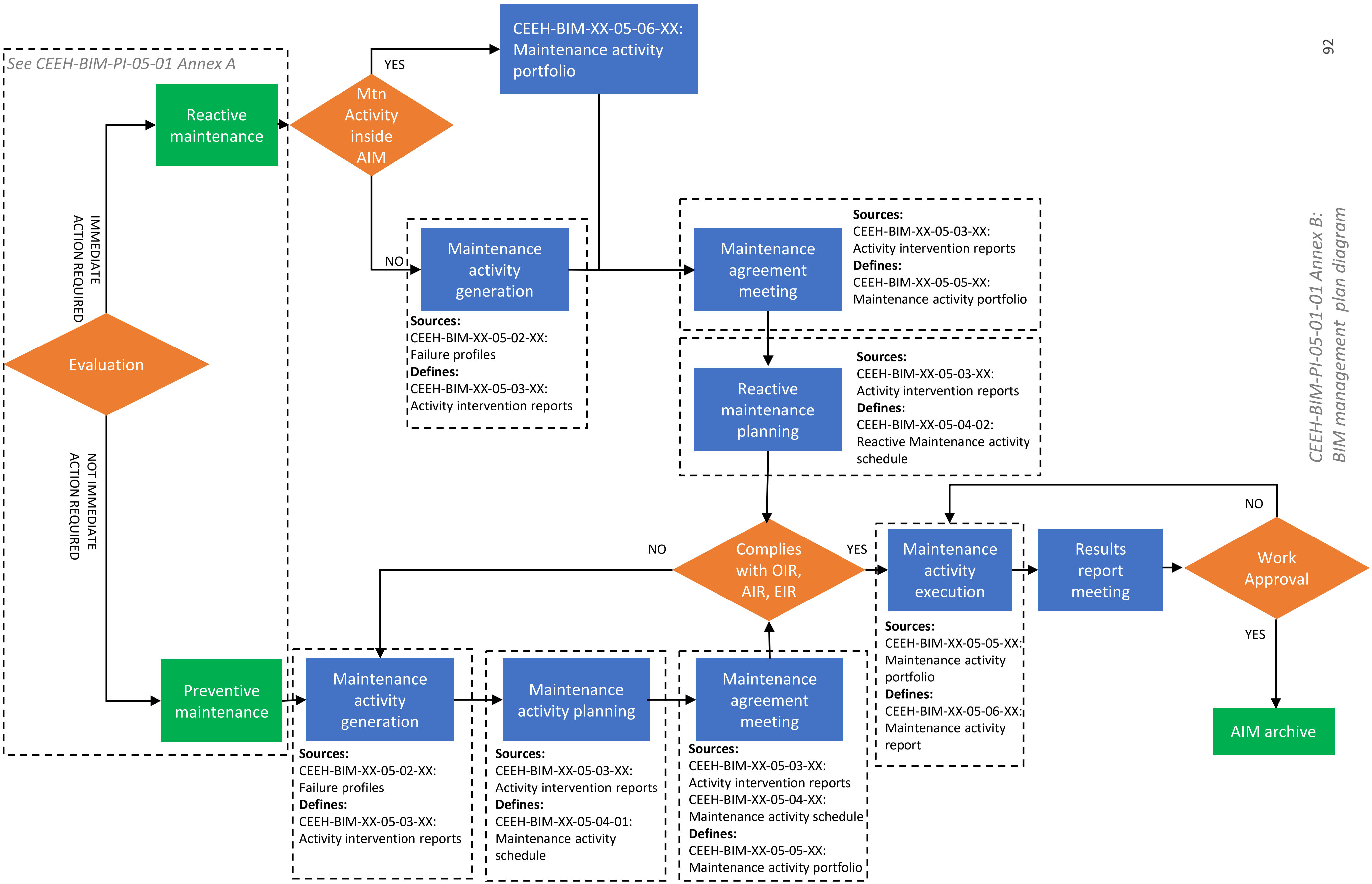
Agreement signature of the interested parties:

Organization

Administration

BIM Management


Maintenance planning
Asset information analysis
Information sources:
AIM
General documentation
Defines:
CEEH-BIM-XX-04-02-XX:
Building component profiles
Operational phase inspection
Sources:
CEEH-BIM-XX-03-02-XX: Operational state inspection formats
Defines:
CEEH-BIM-XX-03-03-XX
Operational phase portfolio
Operational state report meeting
Sources:
CEEH-BIM-XX-03-03-XX
Operational phase portfolio
Defines:
CEEH-BIM-PI-05-01
Maintenance assessment protocol
Failure identification
Sources:
CEEH-BIM-PI-05-01
Maintenance assessment Protocol
CEEH-BIM-XX-03-02-XX:
Operational state inspection formats
CEEH-BIM-XX-05-02-XX:
Failure profiles
Defines:
Performance information
Evaluation
IMMEDIATE ACTION NEEDED
NOT IMMEDIATE ACTION REQUIRED
Reactive maintenance
See CEEH-BIM-PI-05-01 Annex B
Preventive maintenance
See CEEH-BIM-PI-05-01 Annex B



CEEH-BIM-PI-05-01-01 Annex B:
BIM management plan diagram

Understanding the different steps suggested by the reference standardization (task definition, planning, examination, evaluation and reporting), the documentation suggested to be developed in previous stages is organized into these steps, providing an organized workflow diagram in which the different processes are displayed and the formats to support them, providing the maintenance performer a clear path on the tasks to be done.

Thanks to the implementation of this document, the preliminary stages defined in the list and diagrams of the Asset Information protocol (CEEH-BIM-PI-02-01) are now more specific and with a well-drawn sequence, setting not only the different stages but also the decision points where the interested parties shall meet and have agreements about the maintenance works and the documentation to be generated during the citated stages.

In addition, the importance of this protocol relies on being the reference document in each maintenance process of the asset, as there is defined every task and the processes suggested, so the BIM management can assign these different process to its respective task team, and follow the progress of each activity in a clear way.

Despite the fact that a complete maintenance process has not been performed using the BIM maintenance plan on the study case, are included the different documentation and meetings to be done once this maintenance process is planned and executed, providing a guidance inside the diagrams to process these future tasks and make the maintenance plan every time more developed and with more resources inside the portfolio to face the different events that the asset may have.

As the maintenance decisions may vary according with the performance and the lifecycle of each building component, is expected that the processes declared in this protocol may have slight modifications or improvements as the AIM nature, but keeping the same basis and the ability to declare these changes and archive the previous procedures as legacy information for future references.

Consequently, during the delivery formats generation for this maintenance plan it will be necessary to monitor the information required to comply with the stages defined in this protocol, making the correct references to each process and having clear the targets to be achieved by the different activities. For this effort, coordination between the different task teams and BIM management is crucial at each development stage.

4.6. BIM maintenance plan deliverables.

With the development of the maintenance plan protocol, now are defined the documents to be organized by the different task teams at each stage of the plan proposed, as well as their correlation with other documents developed in further stages. In addition, is relevant to define with the organization and the interested parties the level of information to be executed by the BIM crew, based on the requirements and the type of project under study.

As during the analysis of the study case was stated to make the information structure necessary to develop the maintenance based on BIM, in this section will be presented examples of the delivery formats to be applied in each constructive element analysed, focusing on the information level that could be retrieved according with the Mexican information infrastructure.

Considering the information retrieved until now, is possible to develop the documents required until the preventive maintenance schedule stage, in order to provide the maintenance performer the resources needed to perform the different activities and register the results inside the AIM proposed in the information system generated by this study.

In order to make the documentation reliable enough to apply it in the different constructive elements, is decided to exemplify this process in their exposed layers, as many issues that could happen in the inner layers can be controlled if the decay in the external part is treated and maintained first.

Besides, these delivery formats will be divided in two main groups; the first dedicated to the identification of the constructive materials and its possible issues, and the second related to the possible solutions to these issues and a plan proposal to execute these solutions in mode of maintenance activities

Firstly, is needed as a starting point to know the complexity in terms of constructive elements of the asset and the possible issues derived to the interaction of the context with the construction. The formats to be shown according with the maintenance plan protocol are the following:

- **CEEH-BIM-XX-04-02-XX: Building component profiles.** In this format is analysed the constructive element towards its constitutive layers, as well as defining the product used for its construction and its main characteristics. This information is retrieved by means of the manufacturer brochures and technical sheets.

- **CEEH-BIM-XX-05-02-XX: Failure profiles.** With the information recovered in the operational stage inspection of the building, are defined the issues observed and converted now in failures, using as reference external literature to define and evaluate the failure. After this, are proposed actions according with the performance degree evaluated.

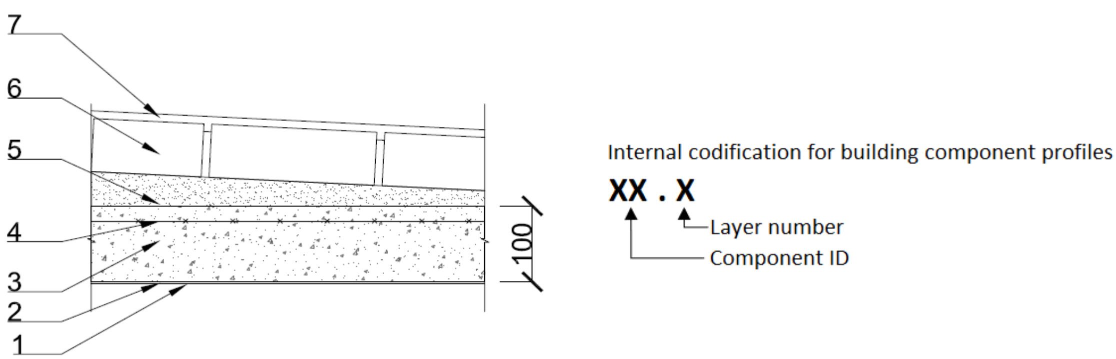
Building component profile	CEEH-BIM-PI-04-02-F02

Objective:
Define the different layers of the constructive component, with its main charactersitics and material properties.

Reference documents:
CEEH-BIM-XX-03-01-XX: Delivery phase portfolio
CEEH-BIM-PI-01-02: Specific events BIM execution plan diagram
CEEH-BIM-PI-02-01: Asset Information Protocol

Component under analysis **F02**

1. Component drawings and layers



Stratigraphy

Composition	Description	Material profile
1	Acrylic ceiling painting	F02.1
2	Interior fine finishing mortar	F02.2
3	Reinforced concrete slab (f'c= 250 kg/cm^2)	F02.3
4	Welded steel mesh 6x6 10/10	F02.4
5	Sloping material (tepetate)	F02.5
6	Clay Brick (0.21x0.14 m) Local	F02.6
7	Cement Mortar finish	F02.7

Component description:
Top roof slab made of field cast concrete with reinforcing steel mesh, with sloping material and weatherproof system.

2. Layer description

1. Acrylic ceiling painting
Coating in white color to enhance light distribution inside the rooms, as well as to give the interior ambient a clean appearance.

2.Interior fine finishing mortar
1 cm thickness mortar layer with the purpose to have a smooth interior ceiling, and avoid any infiltration from the exterior.

3.Reinforced concrete slab
Cast in field (f'c= 250 kg/cm2) as part of the structural system of the building, providing ambient protection to the interior environments, as well as structural stability to each floor.

4. Welded steel mesh
6x6 10/10 pre fabricated modules to enhance the flexural resistance to the concrete slab, considering the big spans of the project.

5. Sloping material
Local high compactability clay (tepetate), used to fill any infiltration void in the reinforced conrete, as well as to form the minimum 2% slope required to drain the roof by the national normativity.

6. Clay brick layer
Locally fabricated (0.21x0.14 m) bricks which main function is to act as humidity barrier to the interior layers, thanks to its low absorptance.

7. Cement mortar finish
Prepared in field, this layer work as a final protection to the clay brick system and avoid erosion effects by wind and water.

Material profile (Acrylic ceiling painting)	**F02.1**

Manufacturer information

Company website	https://www.comex.com.mx/
Factory name	Empresa AGA S.A. de C.V.
Factory address	Avenida Insurgentes, No. 178 Col. Capula, Tepotzotlán Estado de México CP. 54603
Telephone	01-800 7126-639

Local representative	Tienda Comex Suc 533700
Representative address	Calle Hidalgo Oriente 207 Col. Centro Tulancingo de Bravo Hidalgo CP. 43600
Representative telephone	01-775-753-0707
Representative e-mail	b.suarez@gruporoma.com

Product identification

Product commercial name	VINIMEX TOTAL SATINADO BLANCO
Manufacturer product code (SKU)	19A0275100
Product general description	100% Acrylic coating with satined finish with wonderful exterior resistance that could be applied over brick, wood, concrete and other different finshings. Resistant to algae and mold formation.
Inteded use	External and internal finishing coating

Manufacturer reference documents:

	Available	**Link**	**Normative reference**
Technical Specification	x	□	
Security Sheet	x	□	NOM-018-STPS-2015
Other:			

Product features

Characteristic	**Description**	
a) Product state		
Shape	Liquid coating ready to be used	
b) Formats and constructive facts.		
Product presentations	Can	1 & 4 L.
	Bucket	19 L.
	Barrel	200 L.
Color	See catalogue	
Product efficiency	12 to 14 m2/L (Theroetical)	
Suggested layer thickness (wet)	0.1 mm	
Suggested layer thickness (dry)	0.05 to 0.075 mm	

Product features (continues)

Characteristic	Description	
c) Physical and chemical components		
Viscosity	100-120 Krebs units when packed	
Density	1.080-1.320 g/ml	
Washability	More than 10000 cycles	
Ingredient	**Percentage (%)**	**CAS number**
Titanium dioxide	20-50	13463-67-7
Isobutyric acid, monoester with 2,2,4-trimethylpentane-1,3-diol	1-5	25265-77-4
Respirable cristobalite	<1	14464-46-1

For further measures related to these components, please refer to the product security sheet

d) Tolerances

Characteristic	Description
Application temperature	10-33 °C.
Relative humidity treshold	80%
Storage temperature	5-35 °C.
Maximum storage time	24 months

Additional measures related to handling and security

Please refer to the product security sheet

Applicability in other building components

Component	Layer
External- Internal mortar finished wall	W03.1, W03.6
External- External mortar finished wall	W04.1, W04.6
Internal partition wall	W05.1, W05.5
Internal floor slab	F01.1
Sloped roof	F03.1

Material profile (Cement mortar finish)

F02.7

Manufacturer information

Company website	https://www.cemexmexico.com/
Factory name	CEMEX S.A.B. de C.V.
Factory address	Cantera Palma domicilio conocido, Ejido Ignacio Zaragoza Tula de Allende, Hidalgo CP. 42820
Telephone	(773) 732 1162

Local representative	DIMAFESAT
Representative address	Carretera Pachuca Actopan Km. 15 Col. Tecamatl San Agustin Tlaxiaca, Hidalgo CP. 42160
Representative telephone	(743) 79-15181
Representative e-mail	ventas@dimafesat.com.mx

Product identification

Product commercial name	CEMEX MORTERO OPTIMO
Manufacturer product code	N/A
Product general description	Mortar ideal to provide adherence and elasticity for masonry works such as joint between units, finishings, and starting surfaces.
Inteded use	External and internal smooth finishing surface

Manufacturer reference documents:

	Available	**Link**	**Normative reference**
Technical Specification	x	□	
Security Sheet	x	□	OSHA (29 CFR 1910.1200).
Other:			

Product features

Characteristic	**Description**	
a) Product state		
Shape	Powder ready to be mixed with water	
b) Formats and constructive facts.		
Product presentations	Sack	50 kg.
Color	Light gray	
Product efficiency	2.7-3.4 kg/m2	
Suggested layer thickness (dry)	2-3 mm	

Product features (continues)

Characteristic	Description	
c) Physical and chemical components		
pH (mixed)	12-13	
Solubility in water	0.1 to 1%	
Melting point temperature	More than 1000 °C.	
Ingredient	**Percentage (%)**	**CAS number**
Portland cement clinker	40-80	65997-15-1
Gypsum	4-9	7778-18-9
Calcium carbonate	25-45	1317-65-3
Calcium oxide	0-15	1305-78-8
Quartz (Cristaline silica)	0-4.5	14808-60-7
Hexavalent chromium	Variable	18450-29-9

For further measures related to these components, please refer to the product security sheet

d) Tolerances

Characteristic	Description
Application temperature	Not specified
Relative humidity treshold	Not specified
Storage temperature	Not specified
Maximum storage time	Not specified

Additional measures related to handling and security

Please refer to the product security sheet

Applicability in other building components

Component	Layer
External glazed brick wall	W01.2
External exposed brick wall	W02.2
External- Internal mortar finished wall	W03.2, W03.4, W03.5
External- External mortar finished wall	W04.2, W04.4, W04.5
Internal floor slab	F01.2
Plain top roof slab	F02.2
Sloped roof	F03.2

Material profile (Acrylic Weatherproof layer)

F02.7*

Manufacturer information

Company website	http://www.fester.com.mx/
Factory name	Henkel Capital S.A. de C.V.
Factory address	Carretera Panamericana Km. 312 Tramo libre Celaya-Salamanca, Guanajuato CP. 36700
Telephone	01800-3378377

Local representative	Fester Tulancingo
Representative address	Libramiento a Santiago Local 4 Col. Plan de Ayala Tulancingo, Hidalgo CP. 43690
Representative telephone	(775) 755 0619
Representative e-mail	web.fester@henkel.com

Product identification

Product commercial name	FESTER ACRITON
Manufacturer product code	N/A
Product general description	Water based, acrylic elastomeric weatherproof layer with extra fast dry, which enables the best balance of mechanical properties and hydro-repellency.
Inteded use	External roof layers

Manufacturer reference documents:

	Available	Link	Normative reference
Technical Specification	x	□	NMX-C-450-ONNCCE-201
Security Sheet		□	
Other:			

Product features

Characteristic	Description	
a) Product state		
Shape	Acqueous emulsion ready to be used	
b) Formats and constructive facts.		
Product presentations	Can	4 L.
	Bucket	19 L.
	Barrell	200 L.
Color	Red/white	
Product efficiency (first layer)	1 L/m2 in 2 layers	
Product efficiency (end layer)	1.5 L/m2 in 2 layers	

Product features (continues)

Characteristic	Description	
c) Physical and chemical components		
pH	10.5	
Density	1.30 g/cc	
Solids in weight	58.5%	
Solar reflectance	80.70%	
Touch dry	55 min.	
Total dry	2 hr.	
Brookfield viscosity	Up to 41000 Cps.	
Ingredient	**Percentage (%)**	**CAS number**
Titanium dioxide	1-5	13463-67-7

For further measures related to these components, please refer to the product security sheet

d) Tolerances

Characteristic	Description
Application temperature	Not less than 5 °C.
Relative humidity treshold	Not specified
Storage temperature	Between 15 and 30 °C.
Maximum storage time	24 months

Additional measures related to handling and security

Please refer to the product security sheet

Applicability in other building components

Component	Layer
Sloped roof	F03.7

Failure profile	CEEH-BIM-XX-05-02-W02

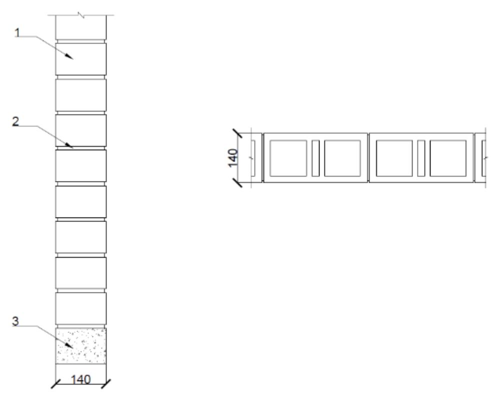
Objective:
Once developed the inspection of the building components, define the possible failures and their impact on the component performance.

Reference documents:
CEEH-BIM-XX-03-01-XX: Delivery phase portfolio
CEEH-BIM-XX-03-02-XX: Preliminary inspection formats
CEEH-BIM-XX-04-02-XX: Building component profiles
CEEH-BIM-XX-02-01: Asset Information Protocol

External literature references:
Vitor Abrantes/ J. Mendes da Silva - ***Simplified method for building anomalies analysis***

Component under analysis **W02**

1. Component drawings and layers



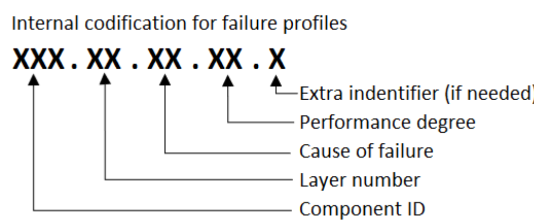
Stratigraphy

Composition	Description	Material profile
1	**Extruded Brick (0.29x0.09 m) Santa Julia**	**W02.1**
2	Joint mortar	W02.2
3	Foundation beam	W02.3

2. Failure description according with CEEH-BIM-XX-03-02-XX results

Inspection document	**CEEH-BIM-PI-03-02-02**
Inspection date	10/01/2020
Results description	Manifestation of efflorescence spots in the top part of the wall due to evaporation in the higher part of the wall.

Failure cause schedule	
Responsible	**Code**
Climatic	CL
Chemical	CH
Biological	BI
Operational	OP
Execution	EX



Failure codification	**W02.1.CL.02.01**
Failure name	Efflorescence
Failure definition	Formation of salts on the surface derivated from dampness on the walls and presence of soluble salts in the constituent materials.
Layers affected	External finishing or coatings
Possible causes	Presence of water in the building component Presence of soluble salts on the consituent materials **Humidity migration phenomena**
Forecast in case of propagation	Safety: Health problems Appearance: Progressive decay of the external finishing Performance: Only related to the material decay

Performance criteria:

Level	**Performance degree**	**Symptoms**
0	No symptoms	0% of the external surface
1	Slight symptoms	0-15% of the external surface
2	Medium	15-30% of the external surface
3	Strong symptoms	More than 30% of the external surface
4	Unacceptable	Not available

3. Maintenance strategy

	Under condition	As the failure was detected and identified after the inspection, is necessary to execute reactive maintenance
x	After failure	
	Preventive Maintenance	
	Opprtunity Maintenance	

4. Suggested interventions

Activity name	Preventive Inspection
Activity description	Visual registration of the possible issues related to the construction component
Performance degree	0-1
Frequency	Low: 12-24 months Medium: 6-12 months High: 3-6 months
Material required	Camera, CEEH-BIM-XX-03-02-XX: Preliminary inspection formats
Workers and extent	1 , complete surface
Possible obstacles	Rain, fog, poor light conditions
Activity name	Surface cleaning
Activity description	Cleaning, preferably dry washing with soft brush in order to keep the original conditions as possible
Performance degree	2-3
Frequency	Low: 5-7 years Medium: 2-4 years High: 1-2 years
Material required	Cleaning material and accesories
Workers	1-2
Possible obstacles	Rain, poor light conditions, temperatures below 5 °C.
Activity name	N/A
Activity description	
Performance degree	
Frequency	
Material required	
Workers	
Possible obstacles	

Applicability in other building components

Component	Layer
External glazed brick wall	W01.1

Failure profile	CEEH-BIM-XX-05-02-F02

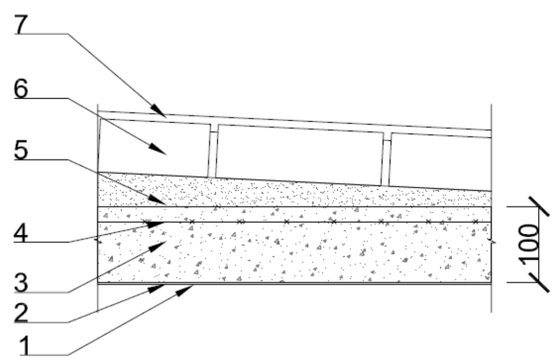
Objective:
Once developed the inspection of the building components, define the possible failures and their impact on the component performance.

Reference documents:
CEEH-BIM-XX-03-01-XX: Delivery phase portfolio
CEEH-BIM-XX-03-02-XX: Preliminary inspection formats
CEEH-BIM-XX-04-02-XX: Building component profiles
CEEH-BIM-XX-02-01: Asset Information Protocol

External literature references:
Vitor Abrantes/ J. Mendes da Silva - ***Simplified method for building anomalies analysis***

Component under analysis **F02**

1. Component drawings and layers



Stratigraphy

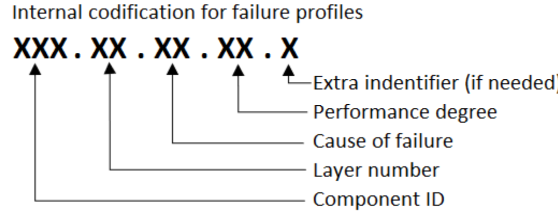
Composition	Description	Material profile
1	Acrylic ceiling painting	F02.1
2	Interior fine finishing mortar	F02.2
3	Reinforced concrete slab (f'c= 250 kg/cm^2)	F02.3
4	Welded steel mesh 6x6 10/10	F02.4
5	Sloping material (tepetate)	F02.5
6	Clay Brick (0.21x0.14 m) Local	F02.6
7	**Cement Mortar finish**	**F02.7**

2. Failure description according with CEEH-BIM-XX-03-02-XX results

Inspection document	**CEEH-BIM-PI-03-02-05**
Inspection date	10/01/2020
Results description	Due to a poor execution during a non registered maintenance, cement mortar layer intended to work as a weatherproof system failed after a year of service life. Finish is falling apart and brick layer 6 is exposed, compromising the service life of the next layers.

Failure cause schedule	
Responsible	**Code**
Climatic	CL
Chemical	CH
Biological	BI
Operational	OP
Execution	EX

Internal codification for failure profiles



Failure codification	**F02.7.EX.04.01**
Failure name	Delamination/Detachment
Failure definition	Detachment of mechanically fixed indpendent cladding or parts of continuous or discontinuous cladding component.
Layers affected	External finishing or coatings
Possible causes	Failure in connection between layer ans support Stress in layer due to unexpeted loads **Bad execution in layer installation** Erosion by context
Forecast in case of propagation	Safety: Possible fall of broken pieces of the layer Appearance: Progressive decay of the external finishing Performance: Possible water infiltration to the deeper layers and dampness manifestation

Performance criteria:

Level	Performance degree	Symptoms
0	No symptoms	Plain surface with no manifestation
1	Slight symptoms	Small cracks in corners or edges
2	Medium	Flaking or delamination in the surface
3	Strong symptoms	Detachment in specific zones of the surface
4	Unacceptable	Complete surface with different grades of damage

3. Maintenance strategy

	Under condition	As the failure was detected and identified after the inspection, is necessary to execute reactive maintenance
x	After failure	
	Preventive Maintenance	
	Opprtunity Maintenance	

4. Suggested interventions

Activity name	Preventive Inspection
Activity description	Visual registration of the possible issues related to the construction component
Performance degree	0-1
Frequency	Low: 12-24 months Medium: 6-12 months High: 3-6 months
Material required	Camera, CEEH-BIM-XX-03-02-XX: Preliminary inspection formats
Workers and extent	1 , complete surface
Possible obstacles	Rain, fog, poor light conditions
Activity name	Refurbishment
Activity description	Partial or total replacement of the damaged layer with the same component material
Performance degree	2-3
Frequency	Low: 3-5 years Medium: 1-3 years High: 12 months
Material required	Cleaning material, finishing material and accesories for installation
Workers	Depend on surface
Possible obstacles	Rain, poor light conditions, temperatures below 5 °C.
Activity name	Layer replacement
Activity description	Total replacement of failed layer for a better quality process in order to ensure the desired performance
Performance degree	4
Frequency	Depend on material Acrylic weatherproof layer: 6 years
Material required	Cleaning material, acrylic weatherproof layer and accesories for installation
Workers	Depend on surface
Possible obstacles	Rain, poor light conditions, temperatures below 5 °C.

Applicability in other building components

Component	**Layer**
Sloped roof	F03.7

Thanks to the implementation of the identification process of each constructive element is possible to register the information related to the performance and way of work of each material based on the data declared by the product manufacturer, as well as any possible reference contact (corporative, manufacturing, sales) for future events happening in the project. In addition, it can be traced and followed any change in the construction component since its delivery stage allowing the user in charge to take relevant decisions related to the treatment of the construction material.

Besides, using a unified format system allows the addition of future information fields, such as the environmental performance data used in some countries where important actions are taken not only to have a strong information basis of the project buts also to know the environmental impact that every stage of the material lifecycle has and how does this impact affects the constructive systems used in the project and look for possible improvements that could be less aggressive with the environment and effective to comply the constructive element performance requirements.

If speaking about the failure profiles, it was achieved not only the link between the inspection and identification processes, but also to have a more detailed knowledge of the failures and their forecast using technical literature references. Using these references as a support, it was set possible levels of damage in accordance with the performance degrees suggested in ISO 15686-7:2017 standard.

Thanks to these performance degrees, will be also possible to evaluate the damage observed during the inspection, and choose between a list of maintenance activities the one that suits best to keep the constructive layer in optimal conditions. As well, the interoperability between the constructive elements is enhanced as some failures can be shared in some layers, avoiding the re-work in each layer and identify in a simpler way the possible solutions.

Next, identified the main failures that can affect in different ways the construction, can be planned common maintenance actions taking into account the local resources and manage them with an efficient calendarization in which the tasks can be performed in the shortest time possible and with the best resource managing: The documents related to these tasks are:

- **CEEH-BIM-XX-05-03-XX: Activity intervention reports.** Using the results of the evaluation of the failures, in this format are developed the maintenance activities required to keep the constructive element in optimal performance, defining their resources and costs according with local government construction price list.

- **CEEH-BIM-XX-05-04-01/02: Maintenance activity schedule.** Towards this document are organized the different activities to be implemented during the building lifecycle, based on preventive and reactive actions with different time occurrence, and defining if some activities can be settled in parallel time lapses as opportunity maintenance and improve processes.

Operative plan for vertical closures				
Constructive component	Layer	Failure name	Codification	Operation required
W01	1	Efflorescence	W01.1.CL.XX.01	
	1	Cracks	W01.1.OP.XX.01	
	1	Biological attack	W01.1.BI.XX.01	
	2	Chemical disolution of mortar	W01.2.CH.XX.01	
W02	1	Efflorescence	W02.1.CL.XX.01	
	1	Cracks	W02.1.OP.XX.01	
	1	Vandalism	W02.1.OP.XX.02	
	1	Biological attack	W02.1.BI.XX.01	
	2	Chemical disolution of mortar	W02.2.CH.XX.01	
W03	1	Efflorescence	W03.1.CL.XX.01	
	1	Dirt stains	W03.1.OP.XX.01	
	1	Cracks	W03.1.OP.XX.02	
	1	Vandalism	W03.1.OP.XX.03	
	1	Biological attack	W03.1.BI.XX.01	
	1	Delamination/Detachment	W03.1.EX.XX.01	
	6	Dirt stains	W03.6.OP.XX.01	
	6	Cracks	W03.6.OP.XX.02	
	6	Rising dampness	W03.6.CL.XX.01	
	6	Delamination/Detachment	W03.6.EX.XX.01	
W04	1	Efflorescence	W04.1.CL.XX.01	
	1	Dirt stains	W04.1.OP.XX.01	
	1	Cracks	W04.1.OP.XX.02	
	1	Vandalism	W04.1.OP.XX.03	
	1	Biological attack	W04.1.BI.XX.01	
	1	Delamination/Detachment	W04.1.EX.XX.02	
	6	Efflorescence	W04.6.CL.XX.01	
	6	Dirt stains	W04.6.OP.XX.01	
	6	Cracks	W04.6.OP.XX.02	
	6	Vandalism	W04.6.OP.XX.03	
	6	Biological attack	W04.6.BI.XX.01	
	6	Delamination/Detachment	W04.6.EX.XX.02	
W05	1	Dirt stains	W05.1.OP.XX.01	
	1	Cracks	W05.1.OP.XX.02	
	1	Delamination/Detachment	W05.1.EX.XX.01	
	1	Deformation	W05.1.EX.XX.02	
	5	Dirt stains	W05.5.OP.XX.01	
	5	Cracks	W05.5.OP.XX.02	
	5	Delamination/Detachment	W05.5.EX.XX.01	
	5	Deformation	W05.5.EX.XX.02	

Operative plan for horizontal closures				
Constructive	Layer	Failure name	Codification	Operation
F01	1	Dirt stains	F01.1.OP.XX.01	
	1	Cracks	F01.1.OP.XX.02	
	1	Dampness	F01.1.CL.XX.01	
	1	Biological attack	F01.1.BI.XX.01	
	1	Delamination/Detachment	F01.1.EX.XX.01	
	6	Delamination/Detachment	F01.6.EX.XX.01	
	6	Breakage	F01.6.OP.XX.01	
	6	Misuse / Lack of Maintenance	F01.6.OP.XX.02	
F02	1	Dirt stains	F02.1.OP.XX.01	
	1	Cracks	F02.1.OP.XX.02	
	1	Dampness	F02.1.CL.XX.01	
	1	Biological attack	F02.1.BI.XX.01	
	1	Delamination/Detachment	F02.1.EX.XX.01	
	7	Delamination/Detachment	F02.7.EX.XX.01	
	7	Breakage	F02.7.OP.XX.01	
	7	Misuse / Lack of Maintenance	F02.7.OP.XX.02	
	7	Drainage block	F02.7.OP.XX.03	
F03	1	Dirt stains	F03.1.OP.XX.01	
	1	Cracks	F03.1.OP.XX.02	
	1	Dampness	F03.1.CL.XX.01	
	1	Biological attack	F03.1.BI.XX.01	
	1	Delamination/Detachment	F03.1.EX.XX.01	
	7	Delamination/Detachment	F03.7.EX.XX.01	
	7	Breakage	F03.7.OP.XX.01	
	7	Misuse / Lack of Maintenance	F03.7.OP.XX.02	

Operation	Action	Code
	General inspection	MA.01.01
	Cleaning (external)	MA.01.02
	Cleaning (internal)	MA.01.03
	Salt Neutralization	MA.01.04
	Repainting (external)	MA.02.01
	Repainting (internal)	MA.02.02
	Partial layer replacement	MA.02.03
	Parts replacement	MA.02.04
	Complete layer replacement	MA.03.01
	Component reconstruction	MA.03.02

Activity intervention report	CEEH-BIM-XX-05-03-F02

Objective:
With the possible failures of the building component identified, the aim of this document is to propose maintenance actions and define its requirements

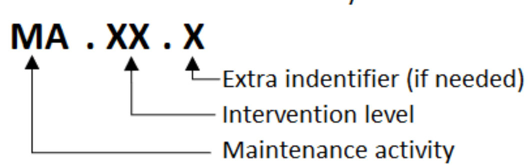
Reference documents:
CEEH-BIM-XX-03-02-XX: Preliminary inspection formats
CEEH-BIM-XX-04-02-XX: Building component profiles
CEEH-BIM-PI-05-01-01: Maintenance assessment protocol
CEEH-BIM-XX-05-02-XX: Failure profiles

External literature references:
Vitor Abrantes/ J. Mendes da Silva - ***Simplified method for building anomalies analysis***
Construction unit costs by Mexico City Goverment February 2020

Component under analysis **F02**

1. Failure description according with CEEH-BIM-XX-03-02-XX results

Internal codification for Activity intervention reports



Intervention level	
Light	01
Medium	02
Heavy	03

Intervention codificati	**MA.01.01**
Intervention name	General inspection
Description	Analysis of the different layers of the constructive component with the objective to determine possible failures and the current state of the component
Layers affected	All

2. Resources under consideration (costs in MXN)

Workforce:

Code	Concept	Unit	Cost	Qty	Sub-Total
N/A	Project Specialist (1)	Labour day	$860.70	1	$860.70
Note: Not considered in the work process				**Total ($)**	**$860.70**

2. Resources under consideration (costs in MXN) continues

Work process:

Code	Concept	Unit	Cost	Qty	Sub-Total
/		m2	/	/	/
/		m2	/	/	/
Note: Considered in the work process				**Total ($)**	**$0.00**

Materials:

Code	Concept	Unit	Cost	Qty	Sub-Total
/		m2	/	/	/
Note: Considered in the work process				**Total ($)**	**$0.00**

Tools and equipment

Code	Concept	Unit	Cost	Qty	Sub-Total
/		m2	/	/	/
Note: Considered in the work process				**Total ($)**	**$0.00**

Maintenance Activity total	$860.70

Applicability in other building components

Component	Failure profile
All components	/

Component under analysis | **W02**

1. Failure description according with CEEH-BIM-XX-03-02-XX results

Internal codification for Activity intervention reports

MA . XX . X

- X — Extra indentifier (if needed)
- XX — Intervention level
- MA — Maintenance activity

Intervention level	
Light	01
Medium	02
Heavy	03

Intervention codificati	**MA.01.02**
Intervention name	Washing of external layer
Description	Washing with high pressure water and tools to remove dirt stains or elements that could affect the performance of the external layer of the constructive element
Layers affected	Exposed brick and mortar wall surfaces

2. Resources under consideration (costs in MXN)

Workforce:

Code	Concept	Unit	Cost	Qty	Sub-Total
N/A	General worker (1)	Labour day	$231.00	1	$231.00
Note: Not considered in the work process				**Total ($)**	**$231.00**

2. Resources under consideration (costs in MXN) continues

Work process:

Code	Concept	Unit	Cost	Qty	Sub-Total
ZB14BB	Natural brick finishing washing	m2	$31.54	1	$31.54
Note: Considered in the work process				**Total ($)**	**$31.54**

Materials:

Code	Concept	Unit	Cost	Qty	Sub-Total
/		m2	/	60	/
Note: Considered in the work process				**Total ($)**	**$0.00**

Tools and equipment					
Code	**Concept**	**Unit**	**Cost**	**Qty**	**Sub-Total**
/	Scaffolding rental up to 10 m. based on tubular steel profiles. Includes wood steps and protective net, as well as transport, mounting and dismounting in field.	m2	$250.00	10	$2,500.00
/	Transport, mounting and dismonting of scaffolding, includes personnel and tools.	unit	$250.00	1	$250.00
Note: Costs up to 15 natural days				**Total ($)**	**$2,750.00**

Maintenance Activity total	**$3,012.54**

Applicability in other building components

Component	Failure profile
External glazed brick wall	W01.1.BI.XX.01
External exposed brick wall	W02.1.BI.XX.01
External- Internal mortar finished wall	W03.1.BI.XX.01
External- External mortar finished wall	W04.1.BI.XX.01
Internal floor slab	F01.1.BI.XX.01
	F01.6.OP.XX.02
Plain top roof slab	F02.1.BI.XX.01
	F02.7.OP.XX.02
	F02.7.OP.XX.03
Sloped roof F03	F03.1.BI.XX.01
	F03.7.OP.XX.02

Component under analysis **W02**

1. Failure description according with CEEH-BIM-XX-03-02-XX results

Internal codification for Activity intervention reports

MA . XX . X

- X — Extra indentifier (if needed)
- XX — Intervention level
- MA — Maintenance activity

Intervention level	
Light	01
Medium	02
Heavy	03

Intervention codificati	**MA.01.03**
Intervention name	Washing of internal layer
Description	Washing with high pressure water and tools to remove dirt stains or elements that could affect the performance of the external layer of the constructive element
Layers affected	Internal mortar wall surfaces

2. Resources under consideration (costs in MXN)

Workforce:

Code	Concept	Unit	Cost	Qty	Sub-Total
N/A	General worker (1)	Labour day	$231.00	1	$231.00
Note: Not considered in the work process				**Total ($)**	**$231.00**

2. Resources under consideration (costs in MXN) continues

Work process:

Code	Concept	Unit	Cost	Qty	Sub-Total
ZB14GD	Washing of wall surfaces with high pressure water	m2	$5.73	1	$5.73
Note: Considered in the work process				**Total ($)**	**$5.73**

Materials:

Code	Concept	Unit	Cost	Qty	Sub-Total
/		m2	/	60	/
Note: Considered in the work process				**Total ($)**	**$0.00**

Tools and equipment					
Code	**Concept**	**Unit**	**Cost**	**Qty**	**Sub-Total**
/		m2	/	/	/
Note: Considered in the work process				**Total ($)**	**$0.00**

Maintenance Activity total	**$236.73**

Applicability in other building components

Component	Failure profile
External exposed brick wall	W02.1.OP.XX.02
External- Internal mortar finished wall	W03.1.OP.XX.01
	W03.1.OP.XX.03
	W03.6.OP.XX.01
Internal floor slab	W04.1.OP.XX.01
	W04.1.OP.XX.03
	W04.6.OP.XX.01
Internal partition wall	W05.1.OP.XX.01
	W05.5.OP.XX.01
Internal floor slab	F01.1.OP.XX.01
Plain top roof slab	F02.1.OP.XX.01
Sloped roof F03	F03.1.OP.XX.01

Component under analysis | **W02**

1. Failure description according with CEEH-BIM-XX-03-02-XX results

Internal codification for Activity intervention reports

MA . XX . X

- Extra indentifier (if needed)
- Intervention level
- Maintenance activity

Intervention level	
Light	01
Medium	02
Heavy	03

Intervention codificati	**MA.01.04**
Intervention name	Efflorescence Neutralization
Description	Neutralization of incompatible materials sticked in the external surface of the building component
Layers affected	Exposed brick and mortar wall surfaces

2. Resources under consideration (costs in MXN)

Workforce:

Code	Concept	Unit	Cost	Qty	Sub-Total
N/A	General worker (1)	Labour day	$231.00	1	$231.00
Note: Not considered in the work process				**Total ($)**	**$231.00**

2. Resources under consideration (costs in MXN) continues

Work process:

Code	Concept	Unit	Cost	Qty	Sub-Total
ZB14BC	Salt neutrlization on external surface, includes material	m2	$24.79	1	$24.79
Note: Considered in the work process				**Total ($)**	**$24.79**

Materials:

Code	Concept	Unit	Cost	Qty	Sub-Total
/		m2	/	60	/
Note: Considered in the work process				**Total ($)**	**$0.00**

Tools and equipment					
Code	**Concept**	**Unit**	**Cost**	**Qty**	**Sub-Total**
/	Scaffolding rental up to 10 m. based on tubular steel profiles. Includes wood steps and protective net, as well as transport, mounting and dismounting in field.	m2	$250.00	10	$2,500.00
/	Transport, mounting and dismonting of scaffolding, includes personnel and tools.	unit	$250.00	1	$250.00
Note: Costs up to 15 natural days				**Total ($)**	**$2,750.00**

Maintenance Activity total	$3,005.79

Applicability in other building components

Component	Failure profile
External glazed brick wall	W01.1.CL.XX.01
External exposed brick wall	W02.1.CL.XX.01
External- Internal mortar finished wall	W03.1.CL.XX.01
External- External mortar finished wall	W04.1.CL.XX.01

Component under analysis | **F02**

1. Failure description according with CEEH-BIM-XX-03-02-XX results

Internal codification for Activity intervention reports

MA . XX . X

- X — Extra indentifier (if needed)
- XX — Intervention level
- MA — Maintenance activity

Intervention level	
Light	01
Medium	02
Heavy	03

Intervention codificati	**MA.02.01**
Intervention name	Repainting (external)
Description	Replacement of old painting and application of a new layer of the same characteristics as the previous one
Layers affected	External wall finishings

2. Resources under consideration (costs in MXN)

Workforce:

Code	Concept	Unit	Cost	Qty	Sub-Total
N/A	General worker (2)	Labour day	$231.00	4	$924.00
N/A	Work supervisor (1)	Labour day	$251.36	2	$502.72
Note: Not considered in the work process				**Total ($)**	**$1,426.72**

2. Resources under consideration (costs in MXN) continues

Work process:

Code	Concept	Unit	Cost	Qty	Sub-Total
LG19LK	Supply and application of acrylic painting with satiny finishing for ceilings, external and internal walls, includes cleaning and materials	m2	$84.98	1	$84.98
Note: Considered in the work process				**Total ($)**	**$84.98**

Materials:

Code	Concept		Unit	Cost	Qty	Sub-Total
/			m2	/	196	/
Note: Considered in the work process					**Total ($)**	**$0.00**

Tools and equipment					
Code	Concept	Unit	Cost	Qty	Sub-Total
/	Scaffolding rental up to 10 m. based on tubular steel profiles. Includes wood steps and protective net, as well as transport, mounting and dismounting in field.	m2	$250.00	10	$2,500.00
/	Transport, mounting and dismonting of scaffolding, includes personnel and tools.	unit	$250.00	1	$250.00
Note: Costs up to 15 natural days				**Total ($)**	**$2,750.00**

Maintenance Activity total	**$4,261.70**

Applicability in other building components

Component	Failure profile
All vertical	/

Component under analysis **F02**

1. Failure description according with CEEH-BIM-XX-03-02-XX results

Internal codification for Activity intervention reports

MA . XX . X

- Extra indentifier (if needed)
- Intervention level
- Maintenance activity

Intervention level	
Light	01
Medium	02
Heavy	03

Intervention codificati	**MA.02.02**
Intervention name	Repainting (internal)
Description	Replacement of old painting and application of a new layer of the same characteristics as the previous one
Layers affected	Internal wall finishings

2. Resources under consideration (costs in MXN)

Workforce:

Code	Concept	Unit	Cost	Qty	Sub-Total
N/A	General worker (2)	Labour day	$231.00	4	$924.00
N/A	Work supervisor (1)	Labour day	$251.36	2	$502.72
Note: Not considered in the work process				**Total ($)**	**$1,426.72**

2. Resources under consideration (costs in MXN) continues

Work process:

Code	Concept	Unit	Cost	Qty	Sub-Total
LG19LK	Supply and application of acrylic painting with satiny finishing for ceilings, external and internal walls, includes cleaning and materials	m2	$84.98	1	$84.98
Note: Considered in the work process				**Total ($)**	**$84.98**

Materials:

Code	Concept		Unit	Cost	Qty	Sub-Total
/			m2	/	196	/
Note: Considered in the work process					**Total ($)**	**$0.00**

Tools and equipment					
Code	**Concept**	**Unit**	**Cost**	**Qty**	**Sub-Total**
/		m2	/	/	/
Note: Considered in the work process				**Total ($)**	**$0.00**

Maintenance Activity total	**$1,511.70**

Applicability in other building components

Component	Failure profile
All vertical	/

Component under analysis | **F02**

1. Failure description according with CEEH-BIM-XX-03-02-XX results

Internal codification for Activity intervention reports

MA . XX . X

- Extra indentifier (if needed)
- Intervention level
- Maintenance activity

Intervention level	
Light	01
Medium	02
Heavy	03

Intervention codificati	**MA.02.04**
Intervention name	Parts replacement
Description	Replacement of missing pieces of the constructive system with stock material keeping the same charactersitics
Layers affected	Roof metal flashing for joints

2. Resources under consideration (costs in MXN)

Workforce:

Code	Concept	Unit	Cost	Qty	Sub-Total
N/A	General worker (1)	Labour day	$231.00	1	$231.00
N/A	Work supervisor (1)	Labour day	$251.36	1	$251.36
Note: Not considered in the work process				**Total ($)**	**$482.36**

2. Resources under consideration (costs in MXN) continues

Work process:

Code	Concept	Unit	Cost	Qty	Sub-Total
GM12FB	Supply and installation of 16 gage galvanized steel gutters, flashings and trims includes material and tools	m2	$6.62	1	$6.62
Note: Considered in the work process				**Total ($)**	**$6.62**

Materials:						
Code	Concept		Unit	Cost	Qty	Sub-Total
/			m2	/	196	/
Note: Considered in the work process					Total ($)	$0.00

Tools and equipment						
Code	Concept		Unit	Cost	Qty	Sub-Total
/			m2	/	/	/
Note: Considered in the work process					Total ($)	$0.00

Maintenance Activity total	$488.98

Applicability in other building components

Component	Failure profile
External glazed brick wall	F01.6.OP.XX.01
Plain top roof slab	F02.7.OP.XX.01
Sloped roof F03	F03.7.OP.XX.01

Component under analysis **F02**

1. Failure description according with CEEH-BIM-XX-03-02-XX results

Internal codification for Activity intervention reports

MA . XX . X

- X — Extra indentifier (if needed)
- XX — Intervention level
- MA — Maintenance activity

Intervention level	
Light	01
Medium	02
Heavy	03

Intervention codificati	**MA.03.01**
Intervention name	Complete layer replacement.
Description	Total removal of old/broken weatherproof layer to be replaced with new material ensuring the correct weathertightness of the building component
Layers affected	External roof finishing or coatings

2. Resources under consideration (costs in MXN)

Workforce:

Code	Concept	Unit	Cost	Qty	Sub-Total
N/A	General worker (2)	Labour day	$231.00	4	$924.00
N/A	Work supervisor (1)	Labour day	$251.36	2	$502.72
Note: Not considered in the work process				**Total ($)**	**$1,426.72**

2. Resources under consideration (costs in MXN) continues

Work process:

Code	Concept	Unit	Cost	Qty	Sub-Total
BL12EG	Manual demolition of top weatherproof layer, includes haulage until 20 m. height	m2	$22.35	196	$4,380.60
FK17DG	Supply and installation of acrylic elastomeric weatherproof system for 3 years life, includes primer and finishing material	m2	$171.41	196	$33,596.36
Note: Considered in the work process				**Total ($)**	**$37,976.96**

Materials:						
Code	Concept		Unit	Cost	Qty	Sub-Total
/			m2	/	196	/
Note: Considered in the work process					Total ($)	$0.00

Tools and equipment					
Code	Concept	Unit	Cost	Qty	Sub-Total
/		m2	/	196	/
Note: Considered in the work process				Total ($)	$0.00

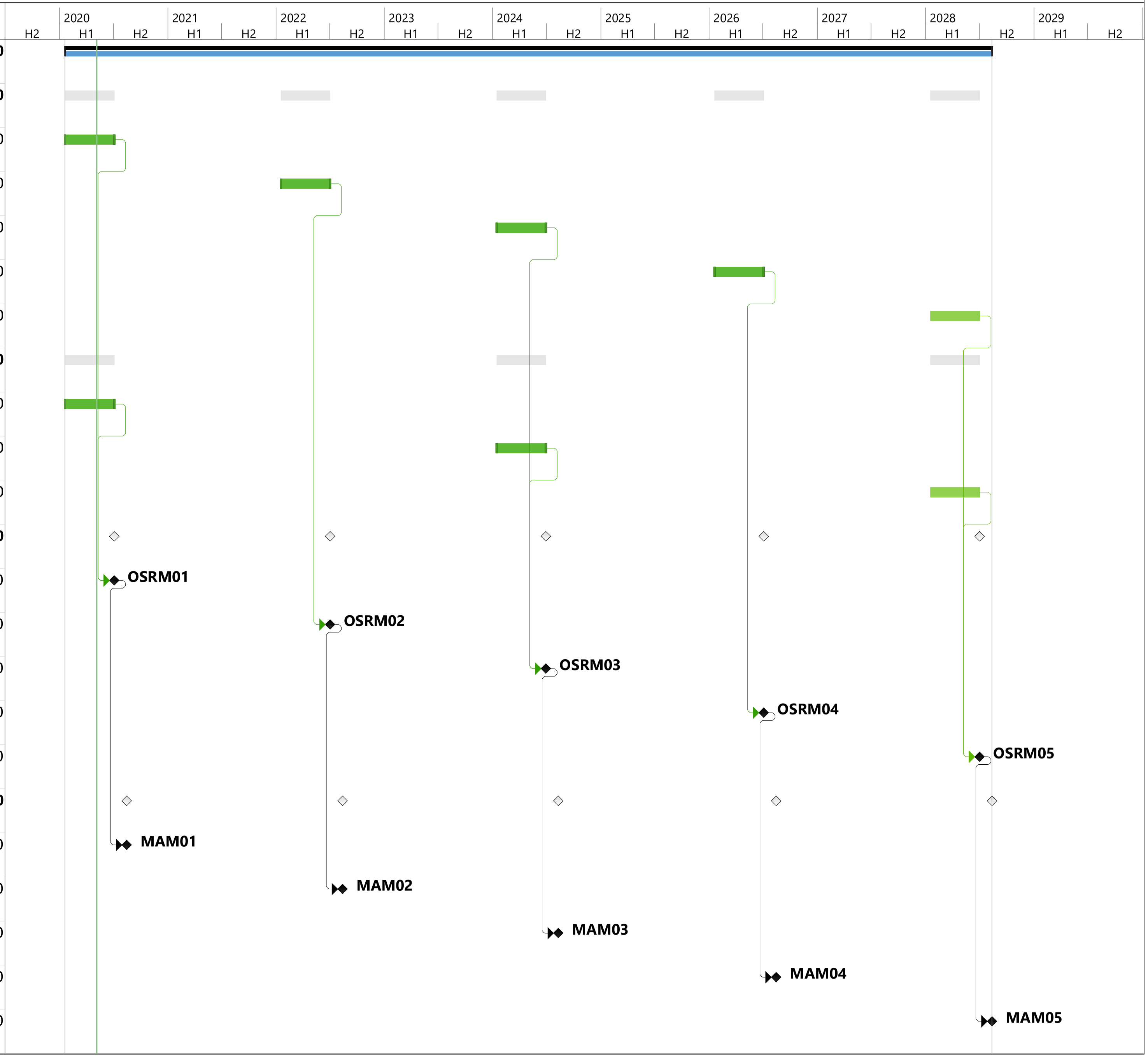
Maintenance Activity total	$39,403.68

Applicability in other building components

Component	Failure profile
External- Internal mortar finished wall	W03.1.EX.XX.02
	W03.6.EX.XX.01
External- External mortar finished wall	W04.1.EX.XX.02
	W04.6.EX.XX.01
Internal partition wall	W05.1.EX.XX.01
	W05.5.EX.XX.01

CEEH-BIM-PI-05-04 -01 Maintenance activity schedule

ID	WBS	CODE	Task Name	Cost (MXN)
1	**MA00**	**MA01.1**	**General inspection**	**$6,885.60**
2	**1.1**	**MA01.1.1**	**General inspection (external)**	**$4,303.50**
3	1.1.1		GIE01	$860.70
4	1.1.2		GIE02	$860.70
5	1.1.3		GIE03	$860.70
6	1.1.4		GIE04	$860.70
7	1.1.5		GIE05	$860.70
8	**1.2**	**MA01.1.2**	**General inspection (internal)**	**$2,582.10**
9	1.2.1		GII01	$860.70
10	1.2.2		GII02	$860.70
11	1.2.3		GII03	$860.70
12	**1.3**	**MA01.1.3**	**Operational state report meetings**	**$0.00**
13	1.3.1		OSRM01	$0.00
14	1.3.2		OSRM02	$0.00
15	1.3.3		OSRM03	$0.00
16	1.3.4		OSRM04	$0.00
17	1.3.5		OSRM05	$0.00
18	**1.4**	**MA01.1.4**	**Maintenance agreement meetings**	**$0.00**
19	1.4.1		MAM01	$0.00
20	1.4.2		MAM02	$0.00
21	1.4.3		MAM03	$0.00
22	1.4.4		MAM04	$0.00
23	1.4.5		MAM05	$0.00



CEEH-BIM-PI-05-04 -01 Maintenance activity schedule

ID	WBS	CODE	Task Name	Cost (MXN)
24	**2**	**MA01**	**Light Maintenance**	**$29,699.70**
25	**2.1**	**MA01.2**	**Cleaning (external)**	**$27,112.86**
35	**2.2**	**MA01.3**	**Cleaning (internal)**	**$1,893.84**
44	**2.3**	**MA01.4**	**Salt Neutralization**	**$693.00**
45	2.3.1		SN01	$231.00
46	2.3.2		SN02	$231.00
47	2.3.3		SN03	$231.00
48	**3**	**MA02**	**Opportunity and medium maintenance**	**$339.92**
49	3.1		Maintenance agreement meeting	$0.00
50	**3.2**	**MA02.1**	**Repainting (external)**	**$169.96**
51	3.2.1		RPE01	$84.98
52	3.2.2		RPE02	$84.98
53	**3.3**	**MA02.2**	**Repainting (internal)**	**$169.96**
54	3.3.1		RPI01	$84.98
55	3.3.2		RPI02	$84.98
56	3.3.3		Results report meeti	$0.00
57	**4**	**MA03**	**Reactive and heavy maintenance**	**$41,513.14**
58	4.1		Operational state report meeting	$0.00
59	4.2		Maintenance agreement meeting	$0.00
60	4.3	MA02.3	Partial layer rehabilitati	$1,620.48
61	4.4	MA02.4	Parts replacement	$488.98
62	4.5	MA03.1	Complete layer rehabilitation	$39,403.68
63	4.6	MA03.2	Component reconstruction	$0.00
64	4.7		Reults report meeting	$0.00

As this will be the first approach to perform the maintenance activities using the information management methodology, is essential that these formats and procedures give enough reliability to trust in this process for future events, this is the reason why is important to test the documentation in field as demonstrated in this study, always considering a continuous improvement.

Therefore, is looked towards the analysis documentation the best understanding possible of the failures that can happen in the constructive elements, so the solutions provided could be accurate and performable considering the technology and workforce available, always leaving room to adapt any new activity or improvement to the system.

Once established the base point for the building components analysed until now, are set 10 main activities in which the main part of maintenance process can be performed, this is in part thanks to the good design and execution of the CEEH project, considering long lasting materials suitable for the activities done inside the school, allowing the owners to take care in a simple way of the building during its life cycle.

In addition, the mild climate and context surrounding the project allowed to keep the performance of the constructive elements for more than 25 years without a documented inspection. This situation reduced importantly the work required during the preliminary inspection, identifying quickly the main failures happening in the project and making sure that the decay of the construction was happening only on the exposed layers with different grades of impact, keeping the internal layers identified but with not enough symptoms to consider a deeper maintenance action at least in a medium time lapse.

For the activity scheduling, it was decided to divide the tasks in three main groups; the first related to the periodic inspections to be done throughout the entire lifecycle of the building, secondly, the preventive maintenance actions inside the light and medium complexity range, and lastly the reactive maintenance section, where the high complexity activities are done in case of an extreme failure of the constructive element.

Additionally to the analysed maintenance actions in the plan, are included the main event meetings agreed in *CEEH-BIM-PI-05-01-01: Maintenance assessment protocol,* with the objective to delimitate the information generation process and making sure that the results of the performed actions are registered and stored inside the AIM. These meeting are pointed mainly for the inspection stage, as every time that these activities happen is essential the communication of the current state of the building to all the interested parties, as well as in the reactive maintenance section, where derived to the complexity of the activities to be done is needed to coordinate these activities to the normal operation of the building avoiding interferences.

Resource coordination is also a crucial factor in this scheduling, therefore the time lapses are set approximately in multiples of 2 year periods in order to look for activity matching and look for opportunity maintenance options; with this, some resources that can imply an unnecessary over cost due to a bad planning can be made more efficient, such as the external scaffolding used mainly for the main vertical closure activities, activities can be adjusted so the normal rental of this resource is for 15 days, can be grouped different activities that use the same resource and the total cost for this tool is only quoted once, making the operation more efficient and less costly.

At this stage of the study, where the base deliverable formats are created and ready to be applied in future maintenance processes, is important to consolidate all the information structure developed until now in a tangible file where the specific information of each component can be input and used as reference for all the different purposes of the asset. To comply with this requirement, is created the following document:

- **CEEH-BIM-XX-05-07: Maintenance model.** By means of the components established during the AIM generation, all the documentation and codes designed to work inside the information management plan will be referred and linked for future references, being this model the interactive part of the maintenance plan.

Analysing the possible solutions to create this model and apply the information structure, is decided to use Revit, as is a well-known software and with more availability in Mexico for the users, as well, the decision was based on its internal information structure, which allows to input all the different processes needed for the maintenance plan in form of parameters inside the software, so every building component converted in an information container inside the program can have its own processes without interfering with other information required by the model.

To refer the different documentation related to each component is decided to use 2 different kind of parameters inside Revit:

1) **Type parameters:** These are used inside the software to call information related to the global component and processes that will not change inside the different component layers, such as the main format document containers established in *CEEH-BIM-PI-05-01-01: Maintenance assessment protocol* and the maintenance activities that will apply for all the component, such as the general inspections and total component reconstruction. In figures 4.7 and 4.8 is displayed as an example the information input in the component W01.

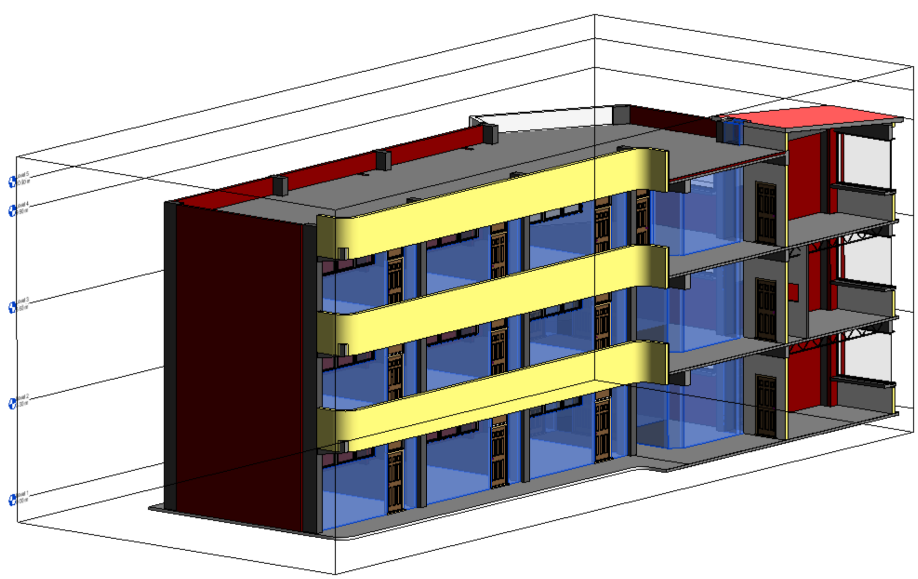
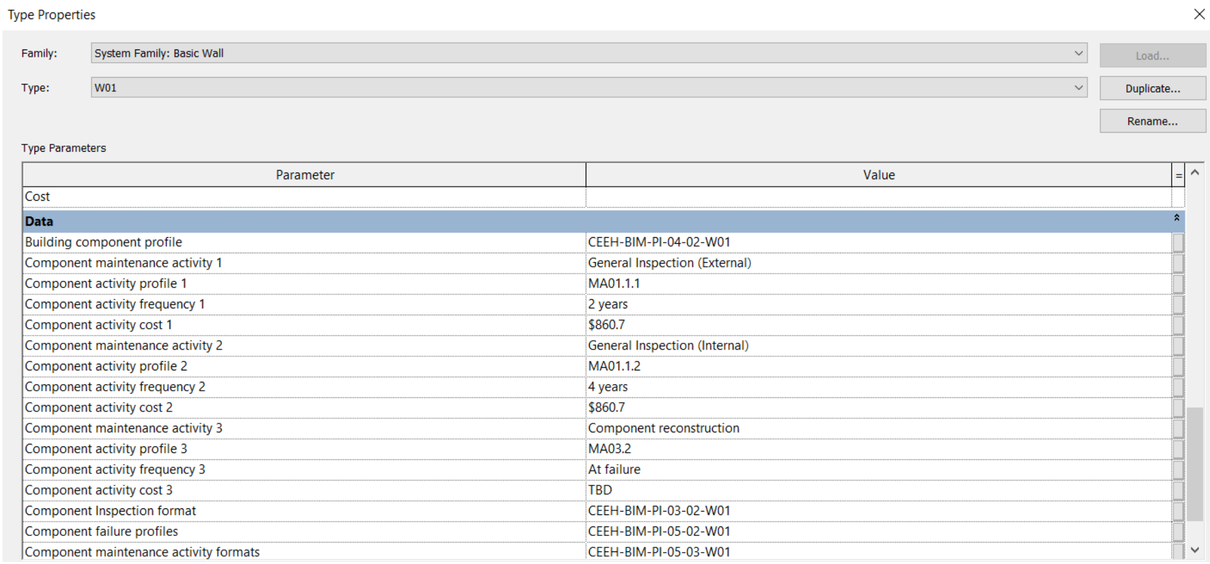


Figure 4.7 W01 component location in Revit (blue) (Source: CEEH-BIM-XX-05-07: Maintenance model)



Type Properties

Family: System Family: Basic Wall

Type: W01

Load... Duplicate... Rename...

Type Parameters

Parameter	Value
Cost	
Data	
Building component profile	CEEH-BIM-PI-04-02-W01
Component maintenance activity 1	General Inspection (External)
Component activity profile 1	MA01.1.1
Component activity frequency 1	2 years
Component activity cost 1	$860.7
Component maintenance activity 2	General Inspection (Internal)
Component activity profile 2	MA01.1.2
Component activity frequency 2	4 years
Component activity cost 2	$860.7
Component maintenance activity 3	Component reconstruction
Component activity profile 3	MA03.2
Component activity frequency 3	At failure
Component activity cost 3	TBD
Component Inspection format	CEEH-BIM-PI-03-02-W01
Component failure profiles	CEEH-BIM-PI-05-02-W01
Component maintenance activity formats	CEEH-BIM-PI-05-03-W01

Figure 4.8 W01 Type parameter input in Revit (Source: CEEH-BIM-XX-05-07: Maintenance model)

As can be seen in figure 4.8, is established a sequence of parameters where the activities related to maintenance are identified and codified according with the previously established system. In addition, are created some extra parameters where other relevant information is added, such as:

- Component activity profile and component activity costs: Obtained from *CEEH-BIM-XX-05-03-XX/ Activity intervention reports*
- Activity frequency: Obtained from *CEEH-BIM-XX-05-04-01/02: Maintenance activity schedule.*

Following this sequence, the update process required at each maintenance event is much quicker, as modifying these type parameters once, all the information is updated in every component with the same characteristics considering the Revit's family categorization criteria, as the software allows this synchronized update.

2) **Project parameters:** On the other hand, these parameters are used to refer specific information processes happening in each layer of the constructive component, as every layer will have its respective materials, failures, and maintenance activities. To be consistent with the information input in the maintenance parameters established in the type section, these are going to be used also, in addition with the following ones:

- Building component layer: Obtained from *CEEH-BIM-XX-04-02-XX: Building component profiles.*
- Failure name and failure profile: Obtained from *CEEH-BIM-XX-05-02-XX: Failure profiles.*

In figures 4.9 and 4.10 can be seen the approach for these parameters in W03 component.

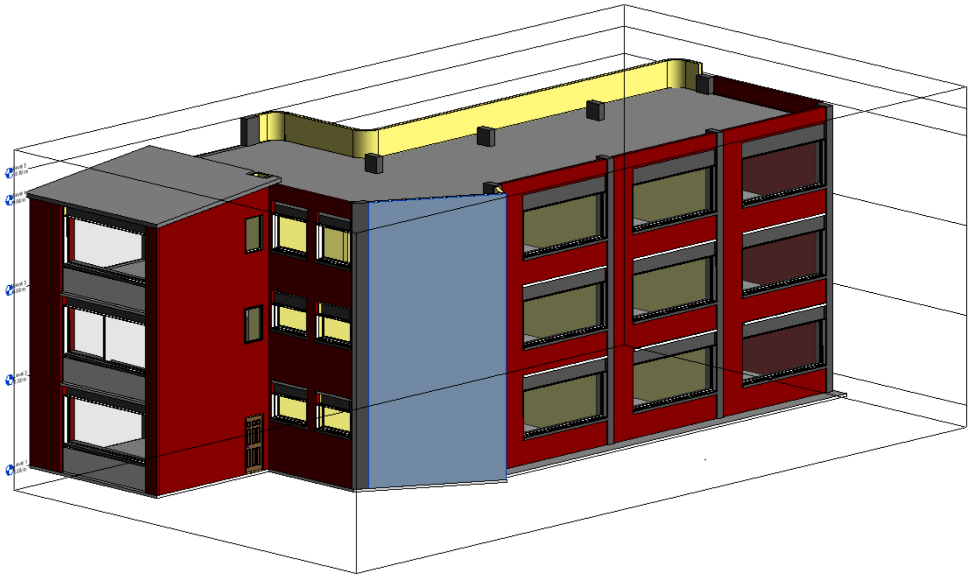
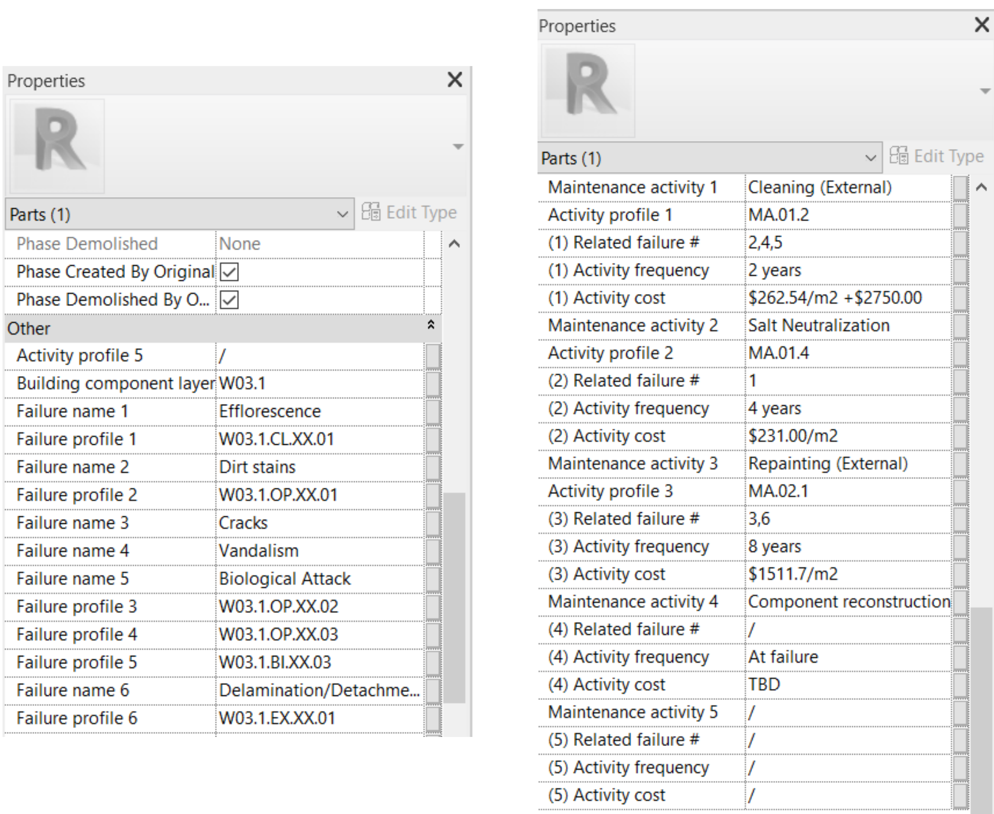


Figure 4.9 W03 component location in Revit (blue) (Source: CEEH-BIM-XX-05-07: Maintenance model)



Properties

Parts (1) — Edit Type

Phase Demolished	None
Phase Created By Original	☑
Phase Demolished By O...	☑
Other	
Activity profile 5	/
Building component layer	W03.1
Failure name 1	Efflorescence
Failure profile 1	W03.1.CL.XX.01
Failure name 2	Dirt stains
Failure profile 2	W03.1.OP.XX.01
Failure name 3	Cracks
Failure name 4	Vandalism
Failure name 5	Biological Attack
Failure profile 3	W03.1.OP.XX.02
Failure profile 4	W03.1.OP.XX.03
Failure profile 5	W03.1.BI.XX.03
Failure name 6	Delamination/Detachme...
Failure profile 6	W03.1.EX.XX.01

Properties

Parts (1) — Edit Type

Maintenance activity 1	Cleaning (External)
Activity profile 1	MA.01.2
(1) Related failure #	2,4,5
(1) Activity frequency	2 years
(1) Activity cost	$262.54/m2 +$2750.00
Maintenance activity 2	Salt Neutralization
Activity profile 2	MA.01.4
(2) Related failure #	1
(2) Activity frequency	4 years
(2) Activity cost	$231.00/m2
Maintenance activity 3	Repainting (External)
Activity profile 3	MA.02.1
(3) Related failure #	3,6
(3) Activity frequency	8 years
(3) Activity cost	$1511.7/m2
Maintenance activity 4	Component reconstruction
(4) Related failure #	/
(4) Activity frequency	At failure
(4) Activity cost	TBD
Maintenance activity 5	/
(5) Related failure #	/
(5) Activity frequency	/
(5) Activity cost	/

Figure 4.10 Project parameters input in Revit. Failures (left) and maintenance activities (right) (Source: CEEH-BIM-XX-05-07: Maintenance model)

To accomplish the information process input of each constructive layer, is required to have a very precise input of information, as the inner categories available in Revit do not allow the grouping possibility mentioned in the type parameters, deriving in possible time and precision issues due to the manual input of information in each different layer.

Therefore, exploring alternative ways to input the information processes in a more efficient way, is decided to rely on a programming script which can help the user to automate the information input and save further issues.

To make this script, is used the mainframe provided by Dynamo, a visual programming interface inside Revit that allows to develop and improve some tasks considering the developed Revit components inside the model. This works by means of task nodes that in sequence allows to create custom algorithms which allow to process a certain amount of data and generate some outputs with the processed data.

These nodes work as an input/output system, this means that the node requires a specific information input according with the process required, to then bring a process data output that complies with the node purpose. The general anatomy of a Dynamo node is shown in figure 4.11.

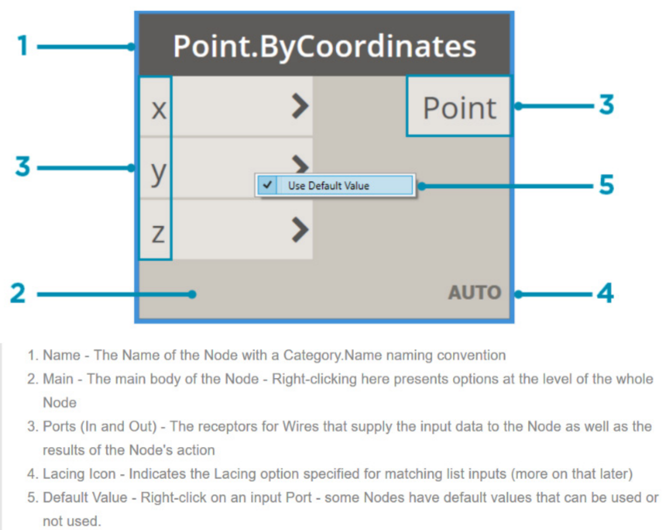


Figure 4.11 Dynamo node components. (Source: primer.dynamobim.org)

In this case, the main task to be developed by the script is to input a determined group of information inputs if an information condition inside the Revit model is complied. As the scope of the script is related to the constructive component layers, is needed to analyse how does Revit understand these layers, and according to its internal structure, the layers are categorized as "parts" inside a Revit component.

Consequently, is proceeded to input manually in all the layers a very first identifier that could help to run the script and find the required "Revit parts" to input the information; in this case is decided to input the building component layer code defined in the building component profiles of each constructive system.

Once input this identifier, is designed in Dynamo a filter process in which all the components that comply with the layer code condition input in the script are displayed.

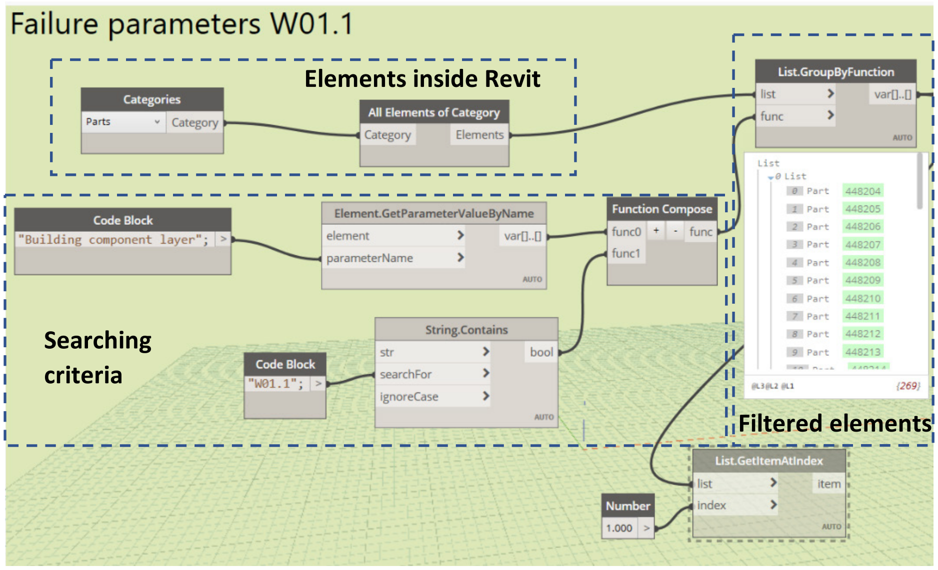


Figure 4.12 Layer filter process script. (Source: CEEH--BIM-XX-05-07 Maintenance model)

Then, with the elements correctly filtered, is possible to establish the information input for each desired parameter inside the model and replicate it for each layer required, in this example are displayed the failure identification parameters.

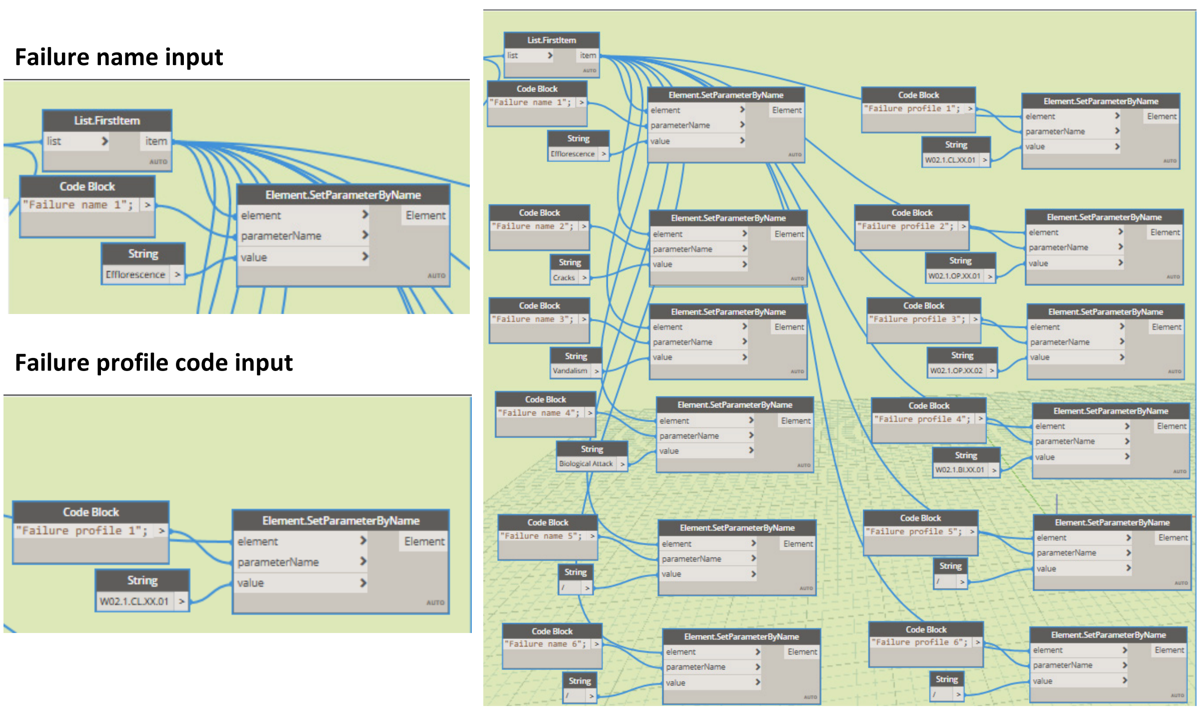


Figure 4.13 Specific nodes (left) and general script (right) for the maintenance parameters input. (Source: CEEH--BIM-XX-05-07 Maintenance model)

In addition, Dynamo allows to create other scripts in the same file for other information processes inside the same Revit Model, such as the ones related to the operative plan and the proposed schedule that also need to be input as part of the BIM maintenance plan.

Nevertheless, during the script creation, this was put into test with the purpose to define the best way that the information input process can be done with less amount of mistakes possible, and it was discovered that Dynamo will have some issues running parallel scripts at the same time. This can happen due to the big amount of information to be input in each process as well as the quantity of Revit parts where the information input needs to be applied.

For this reason, and to make every input process more precise, is decided to leave only one basic script for each information process to be applied in the layers (failures, operative plan and scheduling) bearing in mind to run only one script per time to avoid process malfunctioning or input mistakes. Dynamo offers a solution to enhance this process, which consists in activate/deactivate nodes or complete scripts inside the same file, so the user can run the desired process without modifying others done before or that do not need to be edited at that time.

Applying this “step by step” methodology, is possible to have a quality control of the parameter input inside Revit, allowing the user to check the information to be applied in the layers by information process and detect any mistake before the Dynamo script is run. Whit this improvement, a task that is considered tedious and time-consuming, can be completed using less resources, and better dedicate them to other important tasks inside the BIM maintenance plan.

As a conclusion, this is an important step in the process improving path of the project, as if with this strategy a more accurate model able to reflect the required information processes in less time is achieved, then all the information management process done for this specific asset is complying its purpose, allowing the users and the organization to interact in a better way for all the maintenance processes to be done, thanks to the powerful tools created to make easier the information generation process.

In addition, this model will also comply with the purpose of being able to be improved as all the processes generated inside the AIM, as other kind of parameters could be input in future processes if needed, having now a base procedure in which the users can rely and focus on a real optimization of the processes rather than to solve previous mistakes due to a deficient information model.

Besides, considering the overall delivery formats applied in the project, the maintenance plan has finally a tangible process to be followed, complying with the primary purpose of the study, which is to deliver a structured plan using the technology available, so the owner/administrator can have better tools to control and guarantee a good performance of the constructive elements for a longer time.

5. Conclusions.

5.1. BIM maintenance plan vs traditional process.

Along the development of this study were analysed the different parts related to the information management processes and the possibilities to use this methodology in certain stages happening in a construction asset, from the project delivery to the operation and maintenance. This could be accomplished thanks to the research done in different standardization levels, identifying the key definitions and requirements to have a reliable information system, accompanied by the interested parties involved in the asset management.

During this analysis were described also the challenges that could be faced during the planning, generation and use of the information related to the asset, and emphasizing the collaboration between all the interested parties to form the information resources and methodologies to be followed in order to get the desired process, in this case, a building maintenance plan. The result of this collaboration is a structured information plan with tools where all the processes can be executed and registered using the technology resources such as software and Building Information Models (BIM).

Despite the fact that structuring an information plan for the different specialties involved in a certain project can be time-consuming and can cause discussion between the different parties at the beginning of the work, is demonstrated that this initial effort saves more issues than the ones that it may generate, as with a thoroughly designed plan the owner/organization is setting the operation rules in which all the processes will coexist and develop their tasks.

This is an important progress as every interested party can know the scope of the project in which will be involved and manage its own resources to develop their tasks in a more organized way, allowing the reduction of unexpected issues deriving from the project nature or making them more manageable.

With the use of BIM, all the processes needed on the maintenance plan can be referred and use its interactive phase to follow all the stages of the information plan in a simpler way. This is thanks to the evolution of the project design, passing from the traditional generation of simple lines and shapes to a geometric containers system, capable to collect characteristics and particular processes having every stage ordered and harmonized in one single file, allowing the user to have this first contact with the management plan and go deeper with the precise information if needed.

Besides, implementing the asset management process in the context of a developing country as Mexico, could help to set methodologies in order to solve recurrent issues in the assets, such as the unexpected decay of the constructive elements due to the lack or bad performance of the maintenance activities. Setting the rules and information tools to develop every task, is possible to remove bad habits ingrained in the construction context for long time, such as information voids during the change of maintenance performer, not register every process done or activities left unfinished without control for further processes.

However, in the immediate present of the local construction industry, this initiative can be considered to have drawbacks, as is required a gradual change in the traditional manners done during decades in Mexico, even when thes do not offer a real solution for the problems related to a bad asset management due to deficient information processes.

For this, is important to broadcast the information management process step by step in the industry, motivating the construction owners and maintenance performers to use these strategies to enhance their own performance, and, when the benefits can be tangible with time and constancy, this can derive in a collective effort of all the building industry to make even better constructions and its sub-products.

Is undeniable that the beginning can be time-demanding and continuous training of this methodology will be required in all the companies to walk together with the technological progress offered by BIM maintenance plans, this is expected as the countries where this process is a standard lived the same challenges and needed a gradual transformation of their internal processes. But as well as can be seen the same challenges, is possible to think in the benefits of having more durable constructions and permitting the owners to take better decision and the maintenance crews to perform more efficient solutions, contributing as well to enhance the value of the asset and therefore, helping the organization to reach their value requirements.

Consequently, with better organized companies, improved information processes, and better maintained assets, this small step can contribute to the needed evolution of the Mexican construction industry, rich in history and technical solutions, and demonstrate that tradition and innovation can coexist boosting the progress of a country eager to be better every day.

6. References

Bibliographic sources:

Abrantes, Vítor and Mendes da Silva, Jose R. (2012). Simplified Method for Building Anomalies Analysis.

Alford, L.P., Bangs, John R. & Hagemann, John E. (2000). Manual de la Producción.

Chartered Institution of Building Services Engineers (2008). CIBSE Guide M. Maintenance Engineering and Management – A guide for designers, maintainers, building owners and operators, and facilities managers.

Indiana University (2015). BIM Guidelines & Standards for Architects, Engineers and Contractors.

Nicolella, M. (2003) Programmazione degli interventi in edilizia. Guida al libretto di manutenzione del fabbricato.

Tavares, Lourival A. (2000). Administración Moderna de Mantenimiento.

The Pennsylvania State University (2019). BIM Project Execution Planning Guide, Version 2.2

Standardization sources:

British Standards Institution (2013). PAS 1192-2-2013. Specification for information management for the capital/delivery phase of construction projects using building information modelling.

British Standards Institution (2014). PAS 1192-3-2014. Specification for information management for the operational phase of assets using building information modelling.

International Organization of Standardization (2012). ISO/TS 12911:2012. Framework for building information modelling (BIM) guidance.

International Organization of Standardization (2011). ISO 15686-1:2011. Buildings and constructed assets —Service life planning —Part 1: General principles and framework.

International Organization of Standardization (2014). ISO 15686-4:2014. Buildings and constructed assets —Service life planning —Part 4: Service Life Planning using Building Information Modelling.

International Organization of Standardization (2017). ISO 15686-7:2017. Buildings and constructed assets —Service life planning —Part 7: Performance evaluation for feedback of service life data from practice.

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

International Organization of Standardization (2018). ISO 19650-2:2018. Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling – Part 2: Delivery phase of the assets.

International Organization of Standardization (2019). ISO/DIS 19650-3:2019 Draft International Standard. Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling – Part 3: Operational phase of assets

International Organization of Standardization (2016). ISO 29481-1:2016. Building information models - Information delivery manual - Part 1: Methodology and format

International Organization of Standardization (2014). ISO 55000:2014. Asset management — Overview, principles and terminology

Organismo Nacional de Normalización y Certificación de la Construcción y Edificación (2017). NMX-C-527-1-ONNCCE-2017. Industria de la Construcción – Modelado de Información de la Construcción – Especificaciones – Parte 1: Plan de ejecución para proyectos. *(Building Industry – Building Information Modelling – Specifications – Part 1: Project Execution Plan).*

Online Sources:

Autodesk. Interoperability: Glossary of terms. Autodesk Ltd. Accessed in May 2020, https://www.autodesk.com/solutions/bim/hub/interoperability-key-industry-terms

BuildingSMART International. Industry Foundation Classes (IFC) - An Introduction. BuildingSMART International Ltd. Accessed in May 2020, https://technical.buildingsmart.org/standards/ifc/.

BuildingSMART International. Model View Definition (MVD) - An Introduction. BuildingSMART International Ltd. Accessed in May 2020, https://technical.buildingsmart.org/standards/ifc/mvd/.

Dynamo BIM. What is Dynamo?. Dynamo BIM Organization. Accessed in May 2020, https://primer.dynamobim.org/01_Introduction/1-2_what_is_dynamo.html .

Hamil, Stephen (2012). Building Information Modelling and interoperability. National Building Specification (NBS). Accessed in May 2020, https://www.thenbs.com/knowledge/building-information-modelling-and-interoperability.

McPartland, Richard (2017). What is IFC? National Building Specification (NBS). Accessed in May 2020, https://www.thenbs.com/knowledge/what-is-ifc.