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A Comprehensive Analysis Of The ISO 19650 Attending Their Evolution And Impact On Construction Information Management

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A Comprehensive Analysis Of The ISO 19650 Attending Their Evolution And Impact On Construction Information Management

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Appreciation

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Abstract

Digitalization of the construction industry has caused a paradigm shift in project management, promoting collaboration and efficiency. This master's thesis presents a comprehensive analysis of ISO 19650, examining its evolution and recognizing its impact on construction information management. This study examines ISO Parts 1 and 2 and highlights the fundamental concepts and principles underlying the organization and digitization of information about buildings and civil engineering works, including Building Information Modeling (BIM).

A key element of this study is a detailed case study of a construction project, which serves as a real-world context for examining the practical implications of ISO 19650. This case study provides valuable insight into the challenges faced by project stakeholders and creates conditions for proposing solutions.

A new aspect of this effort is the application of the Value Stream Mapping (VSM) concept to identify inefficiencies and bottlenecks in the construction process. This study aims to provide customized solutions to address the identified issues and optimize the project value chain by leveraging VSM.s

A 3D model is created using Autodesk Revit to better understand the construction project and the proposed solution. The model serves as a visual representation, providing a detailed and comprehensive experience to explain the complexity of the identified problem and suggested improvements.

The results of this study contribute to the broader discussion on BIM, construction project management, and ISO 19650 practices. The result is a nuanced understanding of the development of standards, their impact on information management, and the effectiveness of using concepts such as value stream mapping in addressing construction challenges. Moreover, the integration of 3D models gives concrete dimensions to the proposed solutions and improves the communication power of research results.

This initiative aims to not only advance academic understanding but also provide practical insights to industry practitioners, paving the way for more effective and efficient construction project management in the era of digital transformation.

Keywords:

BIM, construction, design, construction digitalization, BIM software, VSM

Chapter I

Introduction

In the dynamic construction environment, Building Information Modeling (BIM), International Organization for Standardization (ISO) 19650 standards, and Value Stream Mapping (VSM) has proven to be a central element. BIM revolutionizes project management through digital collaboration, ISO 19650 provides a standardized framework for information management, and VSM optimizes processes. Together, they form an essential integrated approach to increase efficiency, minimize errors, and facilitate informed decision-making throughout the construction project lifecycle.

I.1 General context

Building Information Modeling (BIM) is an innovative approach to planning, designing, constructing, and managing construction assets. This includes the creation and use of digital representations of the physical and functional characteristics of the facility. BIM fosters collaboration between stakeholders, improves decision-making processes, and contributes to the overall efficiency and sustainability of construction projects.

BIM in construction enables a holistic view of a project by integrating various dimensions: 3D of form, 4D of time, 5D of cost, 6D of sustainability, and 7D of facilities management. This multidimensional representation facilitates communication and coordination between architects, engineers, contractors, and other project stakeholders throughout the project lifecycle.

The International Organization for Standardization (ISO) developed the ISO 19650 series to standardize information management in BIM environments. ISO 19650 consists of several parts, with Parts 1 and 2 focusing on the organization and digitization of information on buildings and civil engineering works, including BIM. These standards provide a framework for effective collaboration, information sharing, and project implementation.

Construction information management is the effective organization, sharing, and exchange of information throughout the lifecycle of a construction project. This includes processes and systems for collecting, storing, and distributing information to make relevant data available to the right parties at the right time.

Integrating BIM and ISO 19650 into construction information management practices improves collaboration, reduces errors, and improves project outcomes. The standards set by ISO 19650 provide a common framework for information management and ensure consistency and interoperability between projects. As a digital tool, BIM supports these standards by providing a collaborative platform where project participants can collaborate seamlessly.

I.2 Main development goals

This Master's thesis aims to explain BIM's importance and how to transform the construction process by creating and managing digital representations of physical and functional aspects, driving collaboration, efficiency, and informed decision-making throughout the project lifecycle.

Then the ISO standardizes and streamlines the organization and digitization of buildings and civil engineering information to ensure consistency, interoperability, and effective collaboration among project stakeholders.

Concerning the Value Stream Mapping the objective is to identify, analyze, and optimize construction processes by mapping the entire value stream with the aim of eliminating waste, increasing efficiency, and improving the overall flow of information and resources in construction projects.

This work begins with a comprehensive survey of ISO 19650 in the context of international civil engineering projects. Addressing the nuances of his BIM implementation and information management practices based on the ISO 19650 framework, this study draws on a wealth of literature, empirical data, and case studies to identify the challenges, opportunities, and challenges associated with ISO 19650 implementation. The purpose is to analyze the results. At the international level. It aims to highlight the transformative potential of ISO 19650 to improve the implementation of civil engineering projects around the world (Arayici et al., 2018) [1].

In the remainder of this work, we will explore the labyrinth of ISO 19650, exploring its theoretical foundations, practical applications, and lessons learned from real-world case studies. Together, we will embark on a journey to deepen our understanding of how ISO 19650 is shaping the international civil engineering project landscape and revolutionizing the way we imagine, build and maintain the infrastructure that supports the modern world.

I.3 Scientific Methodology

In this master's thesis, scientific methodology revolves around a comprehensive analysis of ISO 19650, focusing on its development and impact on construction information management. This research is developed through an in-depth case study examining a construction project in Tunisia. This methodology involves systematically identifying and documenting various issues, including different types of challenges, that arise during the execution phase. This study uses the principles set out in ISO 19650 Part 1 and Part 2 as a guiding framework to address and resolve these identified issues. At the same time, value stream mapping (VSM) according to ISO 19650 is used to carefully analyze the construction process and optimize the flow of information. A key part of this methodology is the creation of a 3D model using Revit. This provides a visual representation of the construction site and provides a deeper understanding of the task at hand. This integrated approach, combining ISO standards, VSM and 3D modeling, ensures a comprehensive and practical examination of the complexities of construction information management, providing valuable insights and innovative solutions.

I.4 Master's dissertation structure

This Master's dissertation titled "A Comprehensive Analysis of ISO 19650 and Its Impact on Construction Information Management" is based into nine main sections. The introduction sets the stage by outlining the targets of the study, followed by a comprehensive literature review that establishes the theoretical framework.

The second chapter gives an in-depth overview of literature essential for grasping the wide range and practical uses of BIM, as well as how it connects with Lean and VSM methods. This foundation paves the way for deeper discussions and analysis in upcoming sections of the dissertation.

The explication of ISO 19650 Parts 1 and 2 provides a detailed analysis of the standard's key principles and implications. The research methodology section describes the approach and methods used, even as the results section presents findings from Revit modelization and Value Stream Mapping implementation. In the discussion, the effects are interpreted and contextualized inside current literature.

The combination of Revit modeling and Value Stream Mapping in the BIM framework provides significant benefits to both theory and practice in construction project management. This study offers a thorough and practical solution to contemporary construction challenges by improving decision-making, workflow efficiency, collaboration, integrating design and construction processes, and following ISO standards and lean practices that will appear in the results chapter.

The future directions section identifies opportunities for further research, while the conclusion summarizes key findings and gives final reflections. The dissertation concludes with a references segment and optional appendices for supplementary materials. This structured approach guarantees a thorough examination of ISO 19650's impact on construction information management.

Chapter II

Literature Review

II.1 Prelude

In the rapidly evolving field of civil engineering and construction, the introduction of Building Information Modeling (BIM) has ushered in an era of transformation in project management, design, and information sharing. The introduction of BIM principles has redefined the way infrastructure projects are designed, executed, and maintained. An important milestone in the standardization of his BIM practices on a global scale is ISO 19650. This international standard is entitled "Organizing and digitizing information about buildings and civil engineering works, including Building Information Modeling (BIM) - Information management using building information". "Modeling" represents an important step towards his unified framework for BIM implementation in international civil engineering projects.

ISO 19650, part of the ISO 55000 series, provides a comprehensive guide to information management throughout the lifecycle of civil engineering projects. The focus is on principles of collaboration, data integrity, and effective communication. This standard describes a structured approach to information management that includes the creation, exchange, and maintenance of digital information models and associated data. Its adoption not only increases project efficiency but also promises the potential for significant cost savings and improved sustainability practices (ISO 19650-1) [2].

However, the implementation of ISO 19650 is a multifaceted endeavor characterized by the intersection of different global contexts, project sizes, and stakeholder interests. International civil engineering projects are inherently fraught with complexities, including a complex regulatory landscape, cultural diversity among project teams, and the logistical challenges of global collaboration. These subtleties highlight the importance of considering the application of ISO 19650 in this international context. This is because the true effectiveness of the ISO 19650 standard is expressed in this international context (Zhang et al., 2018) [3].

II.2 General ideas and BIM evolution (history)

Building Information Modeling (BIM) has a history that spans several decades, marked by the evolution of technology and the changing needs of the construction industry. Here's a general overview of the key milestones in the history of BIM:

The concept of BIM can be traced back to the 1970s when early computer-aided design (CAD) systems were introduced. However, it was in the 1980s that the idea of integrating data with geometric models began to take shape.

Researcher Chuck Eastman is often credited with coining the term "Building Description System" in the late 1970s, laying the groundwork for BIM concepts.

the 1990s, software developers started creating tools that could manage more than just geometric information. Autodesk's release of the software "Revit" in 2000 is often considered a landmark event.

Eastman, along with Paul Teicholz, Rafael Sacks, and Kathleen Liston, published the influential book "BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors" in 2008, providing a comprehensive overview of BIM concepts.

The construction industry gradually began to adopt BIM practices in the 2000s. Governments and organizations worldwide recognized the potential benefits of BIM in improving efficiency and reducing errors in construction projects.

Various countries started developing BIM standards and guidelines. Notable examples include the United Kingdom's BIM Level 2 mandate and the development of the National BIM Standard-United States (NBIMS-US).

BIM became more globally integrated, and collaborative workflows emerged as a key focus. Cloud-based BIM solutions allowed project stakeholders to collaborate in real-time, enhancing communication and coordination.

The International Organization for Standardization (ISO) released ISO 19650 in 2018, providing global standards for information management using BIM.

The 2020s saw a continued evolution of BIM with advancements in technologies like artificial intelligence, machine learning, and augmented reality. These technologies enhance the capabilities of BIM for design, construction, and facility management. Greater emphasis on sustainability and environmental considerations became integrated into BIM processes.

II.3 BIM Integration With Different Areas

Integrating Building Information Modeling (BIM) with various areas involves linking BIM data and processes with other disciplines within the construction industry and beyond.

II.3.1 BIM Integration with Engineering

Integrating BIM with engineering fields like structural engineering, mechanical, electrical, and plumbing (MEP) engineering greatly simplifies the design process by allowing engineers to work together to study and simulate different systems in a single building model. This merging guarantees better coordination and efficient conflict detection, enabling early identification and resolution of potential issues during the design stage. Enhanced accuracy, decreased rework, and improved efficiency are the outcomes seen during the construction process. Moreover, this method of working together enhances communication among those involved, which in turn helps in the efficient completion of construction tasks. (Krygiel, E., & Nies, B. 2008) [4]

II.3.2 BIM Integration with Architecture

BIM facilitates architects working together by enabling the creation of intricate 3D models that integrate design, spatial connections, and construction information. Collaboration with architectural programs such as Autodesk Revit improves design representation, coordination, and documentation. This integration allows architects to see the project in a more realistic and detailed way, making it easier to make design decisions and changes. Furthermore, it guarantees that all parties are utilizing the latest information, leading to fewer mistakes and misunderstandings. The capacity to model various design possibilities and their consequences also aids in better planning and resource control. In the end, BIM promotes a more united and efficient design process, resulting in improved outcomes and successful project completion. (Eastman, C., Teicholz, P., Sacks, R., & Liston, K. 2011) [5].

II.3.3 BIM Integration with Construction Management

BIM helps with construction management by offering precise project visualization, scheduling, and cost estimation. Combining BIM with construction management software improves project planning, coordination, and communication among stakeholders. This integration enables managers to better predict and handle possible delays by using detailed and dynamic project timelines. Moreover, the accurate ability to estimate costs aids in financial planning and budgeting, guaranteeing that projects stay on track and within budget. By seeing the building process in a 3D format, everyone involved in the project, from contractors to clients, can gain a clearer comprehension of the stages and participate in making better decisions. Moreover, the collaborative aspect of BIM encourages transparency and accountability, resulting in enhanced communication and decreased conflicts during the project's lifespan.(Levy, S. M., & Salvadori, M. G. 2014) [6].

II.3.4 BIM Integration with Facility Management (FM)

BIM data can be used for facility management, allowing facility managers to obtain detailed information on building parts, maintenance schedules, and lifecycle expenses. Incorporating FM software improves the efficiency of building operation and maintenance. This integration enables facility managers to conveniently access and edit data on the building's systems and components, guaranteeing maintenance tasks are completed promptly and in line with the manufacturer's guidelines. Furthermore, the capacity to monitor lifecycle expenses aids in preparing future budgets and making well-informed choices regarding repairs and replacements. BIM helps facility management be more proactive and effective by offering a central, precise, and current source of building data. This leads to decreased downtime, prolonged life of building parts, and enhanced operational efficiency, enabling managers to better predict and deal with possible delays. Moreover, the accurate ability to estimate costs aids in the planning of budgets and finances, guaranteeing that projects stay on track and within budget. By seeing the building process in 3D, everyone involved, such as contractors and clients, can have a clearer grasp of the project stages and make better decisions. Moreover, the collaborative aspect of BIM fosters transparency and accountability, resulting in enhanced communication and decreased conflicts during the project's lifespan. (Underwood, J., & Isikdag, U. 2009) [7].

II.4 Bim Implementation

II.4.1 Opening

Building Information Modeling (BIM) offers the construction sector both tremendous prospects and difficult obstacles.

As BIM evolves and construction processes become more automated, construction professionals' roles will need to evolve to provide more sophisticated services such as 3D: it calls for the creation of 3D Digital Models which represent the Physical and Spatial Characteristics of Building Materials in three dimensions. It allows stakeholders to visualize and comprehend the project's geometry and space relationships through a graphical representation of building designs (Liston, K. 2011) [5].

4D: in order to allow stakeholders to see the construction sequence and schedule of the project, the element of time is integrated into the digital model. 4D BIM facilitates the planning, sequencing and coordination of construction projects by associating building components with schedule information (Succar, B. 2009) [8], 5D: With this, the cost dimension is added to the digital model which allows stakeholders to view and control project costs over its life cycle. 5D BIM enables precise quantity takeoff, cost estimation, and budget tracking through the correlation of construction elements to data on costs (Bryde, D., & Broquetas, M. 2013) [13], and 6D: the digital model shall be extended to include lifecycle information such as facility management and maintenance data. By integrating building information with facility management systems, 6D BIM supports asset management, operations, and maintenance activities throughout the building's lifecycle (Underwood, J., &Isikdag, U. 2009) [7], as well as sharing cost information/data with the project team as part of the BIM integrated project delivery approach (Ocean, J.(n.d.)) [9].

BIM use on building projects is gaining traction in many regions of the world. While the technology underlying BIM has been around for well over a decade, adoption and take-up in the construction industry has been somewhat gradual when compared to industries such as manufacturing and engineering.

This is beginning to change as building clients and government organizations increasingly drive BIM adoption by mandating its usage on their projects, and as technology and implementation challenges improve (Riley, A. C. (2013)) [10].

This article will begin with an overview of current global BIM implementation trends in the construction industry before focusing on the implementation tactics utilized effectively by countries at the forefront of the field. The latter will be based on the study findings of a global investigation of best practices and tactics.

II.4.2 BIM execution trends

BIM Development Generally

BIM principles may be traced back to the early days of computing in the 1960s, with solid

modeling systems emerging in the 1970s and 1980s. Many consider the invention of the ArchiCAD software program in Hungary in 1982 to be the true birth of BIM, whereas the introduction of the Revit software program in 2000 marked a significant turn toward effective BIM application (Bergin 2010) [11].
While the technology underlying BIM has been present for over two decades, implementation and take-up in the construction industry has been somewhat gradual when compared to areas such as manufacturing and engineering. However, there has been a huge shift in momentum over the last five years as technology and implementation challenges have improved and the industry has recognized the significant benefits of using this technology (RICS 2013) [12].

A variety of research is also emerging to address industry implementation difficulties (Bryde et al. 2013 [13], Ahmad et al. 2013 [14], Sacks & Pikas et al. 2013 [15]) and to explain the benefits of effective implementation to key industry stakeholders (Cook 2014, Love et al. 2013) [16].

McGraw Hill (2014) [17] has been conducting extensive global surveys to follow the progress and deployment of BIM in the global construction industry since 2007. They discovered significant change during that time, with particularly dramatic increases in implementation over the last four years. Their survey results across North America revealed that BIM use by contractors increased from 28% in 2007 to 71% in 2012.

In 2013, they surveyed 727 contractors from 10 of the world's top national construction markets: Australia, Brazil, Canada, France, Germany, Japan, New Zealand, South Korea, the United Kingdom, and the United States. They also conducted qualitative market research in China and India to determine BIM trends in two nations that account for almost one-third of the world's population. They discovered a considerable speed-up in implementation.
"Change is sweeping the globe. Project teams are benefitting from faster communications, smaller, more powerful and mobile computers, robust digital modeling tools, and a transformative shift toward integrated delivery processes, all of which are generating positive outcomes, efficiencies, and benefits unimaginable just a few years ago" (McGraw Hill 2014, p. 1) [17].

They also discovered that, while the United States, the United Kingdom, Germany, Canada, and France have led the way in BIM implementation, relatively new adopters in countries such as Australia, Brazil, Japan, Korea, and New Zealand are quickly gaining momentum and even outperforming the more established countries in certain areas.
"BIM usage is accelerating powerfully, driven by major private and government owners who want to institutionalize its benefits of faster, more certain project delivery and more reliable quality and cost. BIM mandates by US, UK and other government entities demonstrate how enlightened owners can set specific targets and empower design and construction companies to leverage BIM technologies to meet and exceed those goals, also driving BIM into the broader project ecosystem in the process" (McGraw Hill 2014, p. 4) [17].

"The adoption of the directive, officially called the European Union Public Procurement Directive (EUPPD) means that all the 28 European Member States may encourage, specify or mandate the use of BIM for publicly funded construction and building projects in the European Union by 2016. The UK, Netherlands, Denmark, Finland and Norway already require the use of BIM for publicly funded building projects." (Autodesk 2014, p.1) [18].

This definitely has substantial implications for the region's BIM implementation.

United States:

The United States has long been a global leader in building information modeling (BIM) development and application (Wong et al. 2009) [19]. The US General Services Administration (GSA) pioneered the use of BIM on public projects in the United States. The GSA is in charge of the building and operation of all government facilities in the United States. They launched a national 3D-4D-BIM program in 2003 through their Public Buildings Service (PBS) Office. They required the use of BIM for spatial program validation on all of their projects in 2007 (Khemlani 2012) [20].
They have also created a set of rules and standards, including an internationally recognized National BIM Standard. The GSA is unquestionably a pioneer in pushing BIM adoption activities (CIBER 2012) [21]. This program has had a tremendous influence on BIM adoption as a major public sector client with approximately 8700 buildings and over 300 million square feet of space across the United States, demonstrating the importance of major client and government leadership for the industry (BuildingSmart Australasia 2012) [22].

According to BuildingSmart Australasia (2012, p. 53) [22], the "GSA is committed to a strategic and incremental adoption of 3D, 4D, and BIM technologies. GSA's next step in BIM implementation is to investigate the use of BIM technology throughout the lifecycle of a project in the following areas: spatial program validation, 4D phasing, laser scanning, energy and sustainability, circulation and security validation, and building elements." According to CIBER (2012) [21], the US government is moving toward requiring BIM on all of their construction projects. The US Army Corps of Engineers, Air Force, and Coast Guard have all embraced BIM.

United Kingdom:

The government of the United Kingdom has implemented a BIM implementation plan for the UK construction industry that is widely regarded as the most ambitious and advanced centrally directed BIM implementation program in the world (HM Government 2012) [23]. The goal is to make the UK industry a global BIM leader in a relatively short period of time (Withers 2012) [24]. The UK Government Construction Strategy was launched in 2011 with the goal of requiring BIM on all government projects by 2016 via a five-year tiered implementation plan. BIM is viewed as critical to the government's goal of saving 20% on procurement costs (Cabinet Office 2011) [25]. This plan has had a significant impact on the UK construction industry, as enterprises face the reality of building the requisite technology capabilities to achieve these criteria. The UK government has established a BIM Task Group to assist both public sector clients and the commercial sector supplier chain in reengineering their work methods to allow BIM delivery (McGraw Hill 2014) [17].

Scandinavian Region:

The Scandinavian region is also a global leader in BIM adoption and implementation. Norway, Denmark, and Finland were among the first countries to adopt model-based design and advocate for interoperability and open standards, and have been instrumental in the development of Industry Foundation Classes (IFCs) and other interoperability initiatives. According to Khemlani (2012) [20], prefabrication is a significant component of building in this region, and model-based BIM technology is well suited for this construction style.
In addition, the various governments in this region provide substantial assistance and incentives for the development and deployment of BIM technology. Since the 1970s, the Finnish government has made significant investments in IT research in the construction industry (Granholm

2011) [26].
They recently published a Universal BIM Guide for the industry, which has received widespread acclaim. The Finnish public sector has been a driving force in BIM adoption, with Senate Properties, a major government organization in charge of managing the country's property assets, leading the way by adopting IFC-compliant BIM modeling since 2007 (BuildingSmart Australasia 2012) [22].

The Danish government strongly supports BIM and actively invests in research and development (Granholm 2011) [26]. The Palaces & Properties Agency, the Danish University Property Agency, and the Defence Construction Service all demand the use of BIM on their projects (BCA 2012) [27]. Denmark is also driving the creation of a new BIM classification standard by Cuneco, a construction productivity center. The goal is to establish this standard not only for Denmark but also for the European Union region (and potentially for global use). This new BIM classification standard is critical for the European Union, and there has been widespread interest in its development (PR Web 2013) [28].

Statsbygg, a business responsible for the building, operation, and development of government facilities in Norway, is in charge of BIM implementation. They have been using BIM for their projects since 2007, and IFC compliant BIM has been required since 2010 (BuildingSmart Australasia 2012) [22].

Singapore:

The Building and Construction Authority (BCA) [27] of Singapore has established a strategy to have BIM extensively deployed on public projects by 2015 (Granholm 2011) [26]. The government has also established a S$250 million Construction Productivity and Capability Fund (CPCF), with BIM as a main aim. The Construction and Real Estate Network (CORENET) program was launched in 2000 as a strategic strategy to foster industry transformation through information technology. CORENET is the infrastructure that allows all project members to communicate information.
The CORENET e-Plan Check system for development applications is another endeavor to boost the usage of BIM in the industry. Architects and engineers can use an online 'gateway' to assess their BIM-designed structures for regulatory compliance. The Industry Foundation Classes (IFC) have been recognized as the standard for BIM deployment in Singapore (BuildingSmart Australasia 2012) [22].

South Korea:

According to McGraw Hill (2014) [17], the level of BIM involvement and implementation in their country is quite low when compared to other countries in their region. This was surprising given South Korea's position as a 'high-tech' country and one of the world pioneers in the use of information technology in school instruction.

Japan:

According to the McGraw Hill (2014) [17] report, Japan has a greater level of BIM application. Their analysis revealed an intriguing finding: nearly all of the questioned contractors reported a favorable Return on Investment (ROI) with their BIM involvement and implementation. BIM was also used extensively for supply chain management, model-driven robotics, and post-construction operations.

Australia:

BIM use in the construction industry is not currently popular in Australia, and there have

been no government mandates to utilize BIM on significant projects. However, interest in BIM adoption has increased in the last five years as a result of a variety of activities to engage and enlighten project stakeholders about the potential efficiency improvements and competitive advantage (CIBER 2012) [21].
These initiatives include the creation of Australasian BIM guides such as the 'National BIM Guide' by National Specification (NATSPEC), 'National Guidelines for Digital Modelling' by the Corporate Research Centre for Construction Innovation (CRC-CI), 'Australian and New Zealand Revit Standards' (ANZRS), and BIM-MEPAUS guidelines and models. The 'buildingSmart' organization (previously known as the International Alliance for Interoperability) continues to play a significant leadership role in BIM development and implementation in Australia, including the establishment of a 'Open BIM Alliance of Australia', which involves an alliance with a number of software vendors to promote the concept of 'Open BIM' (CIBER 2012) [21].

Brazil:

Brazil is the largest country in Latin America and has the greatest economy, so it has a significant impact on the South American continent. The Brazilian construction sector is booming, aided by the hosting of big events such as the FIFA World Cup in 2014 and the Olympic Games in 2016. Many international firms are active in Brazil, impacting the BIM landscape and raising the degree of BIM application in the local market. According to the McGraw Hill (2014) [17] international study of contractors, while the Brazilian industry is still relatively new to embracing BIM, momentum is rising in the country. However, the industry lacks leadership and a coordinated government effort.

Chine:

The Chinese sector is still in the early phases of adopting BIM. According to a 2012 survey conducted by the China Construction Industry Association, less than 15% of 388 surveyed Chinese construction enterprises adopted BIM (McGraw Hill 2014) [17] . McGraw Hill also conducted industry interviews with top professionals to learn more about BIM deployment in China. They discovered that contractors were adopting technology faster than design experts. Designers saw BIM as essentially 'extra work' for a predetermined fee, and hence it lacked incentives.
They also discovered structural impediments in the Chinese sector, such as challenges in changing conventional techniques, and that on many projects, Chinese law requires the design and construction stages to be separated, with contractors not involved in the design stage. This makes collaborative BIM techniques ineffective.

Nonetheless, the Ministry of Science and Technology established a China BIM Union in 2013 as part of the China Industry Technology Innovation Strategic Alliance. BIM standards are being developed, and a draft of the Chinese National Standard 'Unified Standard for BIM Application' has been finalized and released for public comment (Natspec 2014)[168].

India:

According to McGraw Hill (2014) [17] , BIM deployment in India is in its early phases. They do highlight, however, that the Indian construction business is now valued at US$ 140 billion, with a projected significant increase to $620 billion by 2020, and that many international firms are relocating to India.
This will aid in the adoption of BIM in the market. They discovered that, while major construction companies are increasingly adopting BIM in significant project sectors such as hotels and airports, it is not yet being widely embraced. As a result of the sporadic usage of BIM, implementation costs are significant; the sector requires more broad training and development.

II.4.3 Investigation's goal

Numerous countries are setting the standard for BIM deployment. As a result, the second element of this study's research approach was to conduct an analysis of the main factors in these countries that promote successful BIM adoption. The investigation's goal was to identify best practices and creative ways being used around the world that may be used by everyone. The following is a summary of the key findings of this study.

Government Policies and Regulations: Support policies and regulations to mandate or encourage the adoption of BIM in public infrastructure projects have been put in place by a number of countries. For example, mandates and frameworks to use BIM in public funding projects have been established by countries such as the United Kingdom, Singapore, and South Korea. These policies create an environment favorable to widespread implementation of BIM, with a view to driving industry-wide acceptance (Smith, D. K., & Tardif, M. 2016) [29].

Industry Initiatives and Standards: By developing standards, guidelines, and training materials, industry organizations and alliances are playing an essential role in promoting the adoption of BIM. Interoperability, knowledge sharing, and best practices in the construction industry around the world are key objectives of collaborative efforts like BIMForums in the United States as well as BuildingSMART International(Bryde, D., & Broquetas, M. 2013) [13].

Organizational Strategies and Change Management: Successful implementation of BIM includes a strategic approach to organizational change, such as leadership commitment, training for staff, and process modernization. Companies that invest in developing BIM capabilities, fostering a culture of innovation, and addressing barriers to adoption are better positioned to realize the full benefits of BIM implementation (Succar, B., & Kassem, M. 2015) [30].

Technological Advancements: By enhancing functionality, ease of use and interoperability, continuous improvement in BIM software and technology is contributing to its widespread adoption. The way construction projects are planned, designed, and executed is being revolutionized by emerging technologies such as cloud-based BIM platforms, virtual reality VR, and AIAI integration, (S.Azhar, Nadeem, A., Mok, J.Y., Leung, & B.H. 2015) [31].

II.4.4 Best Practice & Innovative Approaches to BIM implementation

Government & Industry Leadership:

According to the findings, the most important aspect for successful BIM deployment is national leadership and coordination in order to maximize efficiencies and avoid the numerous difficulties caused by fragmented and disjointed approaches. This leadership should be led primarily by government organizations, but it also requires the participation and collaboration of significant industry participants such as major private sector clients, contractors, and industry/professional groups. Given the worldwide character of construction activity, global leadership is also required to allow the global transportability of BIM implementation (McGraw Hill 2014) [17]. .

The new European Union Public Procurement Directive (EUPPD) by the European Parliament to encourage, specify, or compel the use of BIM for publicly funded projects in the 28 European Union member countries is an example of this top level leadership (Autodesk 2014) [18]. According to Autodesk, this will increase the European Union construction industry's global competitiveness in gaining international building contracts.

These worldwide activities must also be supported by international BIM standards and procedures that are 'borderless' and applicable in all countries. There is a lot of duplication of work in BIM development around the world, and global leadership can help a lot by coordinating it and bringing it all together for mutual benefit NBS (2014) [32].

Owner-driven BIM provides the best likelihood of success (McGraw Hill 2014 [17], CIBER 2012 [21]). Mandates issued by the government appear to be the most effective. Mandates requiring the use of BIM, such as those enforced by significant government entities in the United States, The United Kingdom and Singapore have been extremely effective in providing the impetus for shifting the sector toward BIM. Firms are effectively presented with the premise that if they do not become BIM proficient, they will not be able to secure future work with these entities - a significant influencing factor. Industry organizations and professional associations play a significant role as well.

Their jobs must be collaborative in order for multidisciplinary techniques to be used. Major contracting and consulting firms must also provide leadership to urge their supply chain to comply with BIM regulations. This help is critical, particularly for smaller businesses, which arguably require the greatest aid.

The Business Case and Competitive Advantage:

Competitive advantage is also an important motivator for BIM implementation. The construction sector is characterized by firms that take a 'wait and see' mentality and are unwilling to invest in pioneering new processes. However, as corporations increasingly see their competitors obtaining a competitive edge through their BIM expertise, the more temptation there is to join on board.

This is not limited to national considerations. It is apparent that organizations who lack BIM expertise will increasingly struggle to get work on multinational projects. This competitive advantage has far-reaching consequences. Even if a firm does not work on foreign projects, it must be globally competitive since it will increasingly compete against multinational firms with similar competencies on local initiatives.

The business case for all construction sector actors must be a significant concern. If the business value and return on investment (RIO) of BIM deployment are not sufficiently explained, a barrier will be created. This is the business bottom line. Currently, firms with cynical and unfavorable attitudes on the value of investing in the requisite BIM technology and training are impeding BIM deployment, owing to problems in explaining the business case for these organizations.

The McGraw Hill (2014) [17] paper on the commercial value of BIM in the key global construction markets is an excellent illustration of what is required to effectively communicate the benefits to businesses. According to their large survey of contracting organizations in North America, Brazil, Europe, and Asia Pacific, 75% of enterprises had a good return on investment in their BIM program, with reduced mistakes and omissions, less rework, and lower construction costs highlighted as the main benefits.

The firms also estimated that the percentage of their work that involves BIM will increase by 50% over the next two years, indicating that firms must engage in BIM or risk being left behind with potentially severe commercial implications.

It is probably even more vital to articulate the business case for industrial clients, as they will be the key drivers of BIM deployment. One typical explanation given by firms for not investing in BIM is that their clients do not require them to utilize BIM. A growing body of evidence from national and international studies indicates that BIM adoption provides significant value to clients through improved information sharing, reduced design errors, improved design quality, increased productivity, and reduced construction times and costs (CIBER 2012 [21], NIBS 2013, McGraw Hill 2014) [17].

National & Global Standards:

Consistent national and worldwide standards are required to achieve the efficiencies envisioned by this technology. It makes no sense to have a wide variety of various platforms and piecemeal approaches to BIM development. worldwide leadership can help to secure national and worldwide collaboration. Clearly, if BIM is to be the future of international projects, then universal standards must be developed. The usage of Industry Foundation Classes (IFCs), a vendor-neutral framework that allows models to be worked on independently of individual applications, will be critical. This technique continues to be widely misunderstood (NBS 2013)[47].

According to the NBS (2013, p.2)[47], the following are required for these Standards. "BIM Guidelines – to move the industry to the use of world best practice BIM protocols in support of collaborative design practice (BIM can assist the industry to move to integrated, whole of life cycle property solutions and away from the current silo mentality). Product Data and Libraries – access to BIM-compatible product information in an open format that is properly specified, fit for purpose and can be correctly integrated into the project model. Process and Data Exchange – need for business process changes to facilitate integration of the briefing, design, construction, manufacturing and maintenance supply chain throughout the entire life of a built facility, achieved through effective exchange of BIM- based data and information. Regulatory Framework – the development of automated building design performance assessment and compliance checking based on the object-based information models that are developed through BIM processes. In order to achieve maximum benefit, BIM needs to be extended in to the geospatial domain, so that models can be tested within a virtual urban and regulatory context".

National & Global BIM Product Databases & Libraries:

It is also critical for BIM implementation to provide standard BIM Product databases and libraries. Building Smart (2012) [22] emphasizes the UK government's recent attempt to provide free universal access to its infrastructure.

As an example of what is required in the industry, consider the National BIM Library. Access to universal, free, and accessible online BIM building product data and libraries with worldwide consistency is anticipated to have a significant impact on implementation levels.

BIM Protocols & Legal Contracts:

Another key aspect is the legal and contractual implications of using BIM models. Due to the vast number of project participants contributing to the BIM model and/or relying on the accuracy and quality of the information in the model, legal liability is questionable. Several projects are being established in various nations to solve this issue, but there is still much work to be done.

The American Institute of Architects (AIA) has created a BIM protocol paper (Conditions of Contract) for using BIM that is widely regarded as a good legal model. This protocol creates a legally binding relationship between the parties in order to reach an agreement on the following major issues: protocols, model development level, and model elements (CIBER 2012 [21]). The National Institute of Building Sciences (NIBS) in the United States has studied the introduction of project-based liability insurance coverage to mitigate the risks associated with an integrated

design and construction strategy. Intellectual Property (IP) rights and data ownership must also be addressed more effectively.
Many businesses are hesitant to share databases and information that they regard as their own intellectual property which gives them a competitive advantage. Cost databases used by project cost management experts are one example. Appropriate audit and risk management control methods are also required.

Project Procurement Systems - Integrated Project Delivery:

The development of project procurement systems based on Integrated Project Delivery (IPD) systems is widely regarded as critical for the successful adoption of BIM and all of the benefits it may possibly bring to the project (Building Smart 2012 [22], McGraw Hill 2014 [17], CIBER 2012 [21]).
The American Institute of Architects and McGraw Hill created the working definition of Integrated Project Delivery that is still extensively used today.

'Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction. IPD principles can be applied to a variety of contractual arrangements and IPD teams can include members well beyond the basic triad of owner, architect, and contractor. IPD uses business structures, practices, and processes to collaboratively use the talents and insights of all participants in the design, construction and fabrication process. Beginning when the project is first conceptualized, the integrated process continues throughout the full life cycle of the facilities. (AIA 2007, p. 1) [33].

Building Smart (2012) [22] contends that standard contracts for IPD procurement systems must be developed that can be extensively used across the industry. They contend that IPD contracts are typically produced on an ad hoc basis for individual projects, preventing wider implementation and understanding. This raises the risk perception of clients considering the adoption of IPD delivery methods.

Quality of the Model:

Legal difficulties are inextricably linked to the quality and accuracy of the BIM model. BIM models necessitate the input of massive volumes of complicated data from a diverse set of project participants. The quality, comprehensiveness, and accuracy of this information are critical to the model's success.
According to research, one of the biggest concerns with BIM models is model quality (Smith 2013) [34] - if parties don't trust the information in the model, it has clear ramifications. Smith (2013) [34] discovered, for example, that quantity surveyors/cost planners frequently use traditional quantification methods rather than the automated quantities capabilities of BIM models due to worries about the model's correctness. Clients must be willing to spend in the necessary resources to attain the requisite quality levels for BIM models, which can be tough for clients who are focused on reducing 'up front' expenses during the design development stages.

BIM Maturity Models & BIM Engagement Index:

BIM competence is directly proportional to experience and BIM implementation (McGraw Hill 2014) [17]. To assess BIM capabilities, BIM maturity models and engagement indices are now being employed. According to Kassem et al. (2013) [35], most models are centered on a particular organization, but there is a need for national maturity/engagement scales and models. BIM adoption surveys can serve as a starting point for country-wide BIM maturity assessments.

BIM adoption surveys conducted in Australia, the United Kingdom, and the United States were referenced by Kassem et al. as examples of metrics that can be used in country BIM maturity models. The benefits of establishing whether a country is BIM-mature, BIM-maturing, or BIM-infant are described by BIM Think Space (2013, p.1) [36].
“If done properly, a country’s BIM maturity highlights what has been achieved, what is still lacking, and what can be learned from others”. According to McGraw Hill (2014) [17], the benefits of a BIM engagement index include the fact that the more engaged organizations are with BIM, the greater their capacity to reap the benefits. Since 2009, they have employed a consistent worldwide engagement indicator, with BIM adoption levels classified as Light (less than 15% of projects), Medium (15-29% of projects), Heavy (30-59% of projects), and Very Heavy (60% of projects or more). In their 2013 global study, mentioned earlier in this paper, they discovered that the majority of contractors (60%) worked at a light or medium level, but that more than two-thirds of firms expected to be heavy or very heavy BIM implementers within two years.

BIM Education, Training & Research:

BIM education, training, and research are critical for driving not only implementation but also industry evolution. Tertiary-level BIM education is required so that graduates entering the sector have the appropriate BIM knowledge and capabilities. According to Natspec (2013, p.1) [37], "an industry reluctance to change, a 'wait and see' approach, and a scarcity of experienced/educated BIM practitioners/technicians/educators are slowing the inevitable uptake of BIM in the AEC industry. It is clear that tertiary education institutions, with the support of government and industry, must fully integrate BIM education into their curricula in order to provide the AEC industry with the 'BIM-ready' graduates needed for the collaborative BIM working environments of the future."
They conducted international research on tertiary BIM education and discovered that present BIM education focuses on the usage of specific BIM software, but that there is an urgent need for education in open BIM ideas, BIM management, and working in collaborative BIM environments.

This instruction should encompass the entire industry. Project clients (both public and private sector) must be given special attention because they ultimately have the most influence over BIM deployment on their projects. This education must initially include BIM awareness, followed by the business benefits and return on investment, the development of technical skills and knowledge, and a functioning grasp of BIM as a collaborative working tool (Building Smart 2012) [22].

The development of a variety of pilot projects and case studies across a wide range of projects across all market sectors and project client types is also crucial. Many case studies and pilot projects tend to focus on larger, high-profile initiatives where project clients have the financial resources to invest in the technology. More case studies and pilot projects are needed for the larger industry, including all sectors large and small, to properly convey to customers the business benefits of investing in BIM on their projects.

Business Changes:

The transition to BIM capabilities and competence necessitates a re-evaluation and re-engineering of business procedures. Moving to BIM might have substantial commercial consequences. While software and technology often demand significant upfront investment, the greatest cost is associated with employee training and development. While the goal is to reap benefits and gain a competitive edge in the long run, the development expenses are enormous, particularly in market sectors with severe rivalry and poor profit margins. Many businesses do not have the financial resources to invest in existing and future digital technologies and capabilities.

The additional problem is that technology is always improving, and a lot of time and money can be spent on software and training with uncertain results. The 'pioneering' method can be risky since enterprises become 'test pilots' for specific technologies while competitors wait in the wings to see if the 'testing' results in commercial value and competitive advantage. However, for enterprises that aspire to be important players in the construction sector, particularly at the upper end, this 'wait and see' approach is no longer possible.

Another problem for businesses is altering the mindset of employees to embrace and evolve with this new technology. Many businesses consider staff members' conservatism and incapacity to adapt as a major impediment to serious change. However, the increasing momentum of BIM implementation in many countries around the world, particularly where government/major private sector clients issue mandates for BIM implementation, has made construction professionals realize that they will be left behind if they do not evolve with this technology and develop expertise. Younger professionals who are more open to digital technology and change pose possibly the greatest threat to more senior workers who are reluctant to change.

II.4.5 Outcome

International trends have indicated a significant increase in BIM deployment in key construction markets over the last few years, and this is expected to accelerate sharply in the next years. Government mandates in key industry sectors such as the United States and the United Kingdom, as well as large private sector clients and contractors that recognize the benefits of this technology, are driving this (Kwon, H., (2012)) [38]. These advancements and activities are driving wider implementation as other countries see that if they do not keep up with countries leading the BIM field, their markets will be left behind. It is obvious that the sooner organizations invest in BIM skills, the better positioned they will be to take advantage of various projects and capabilities as they evolve. However, this does necessitate future investment, and one of the major challenges here is that many enterprises in the industry are undercapitalized and run on extremely low profit margins, limiting their ability to invest in this technology for long-term benefits. This is undoubtedly one of the most difficult implementation difficulties, but it might also serve as a quality control mechanism by progressively driving less capable enterprises out of the market (Raja, R.A., (2014)) [39]. Finally, it is obvious that the decade of stagnation is giving way to rapid BIM adoption rates as organizations understand they would be left behind if they do not embrace and evolve with the BIM revolution.

The creative approaches to BIM implementation utilized by industry leaders (government, public/private sector customers and enterprises) may be too far ahead for many in the industry who have yet to embark down this route in any meaningful way. Fundamental changes in business procedures are required for these organizations that are falling behind, and this all takes time to establish. However, the competitive advantages that their competitors have already realized are more likely to act as a catalyst for change than anything else.
The longer firms delay their entry into the BIM world the further other firms with these capabilities will progress and add to their competitive advantage. The strategies taken by leading firms to embrace these technological tools and adapt their business practices accordingly should

provide considerable inspiration and guidance for others (Withers, I. (2012)) [24].

Given the globalization of construction activity and the removal of international boundaries/barriers, construction firms will increasingly compete for work not only against local competitors with better BIM capabilities but also against international competitors who may bring highly developed BIM capabilities and expertise to the bidding table. In a worldwide market dominated by enterprises with minimal or no capabilities in the field, the strategic benefits of having competence in BIM implementation are extremely evident (McKane, M., (2014)) [40].

II.5 BIM dimensions and BIM levels

II.5.1 Preface

Building Information Modeling (BIM) helps you create and manage information models in custom data environments that contain both graphical and non-graphical information (Ingibjörg Birna Kjartansdóttir) [41]. As the project progresses, more information will be associated with the 3D model.

The simplest way to describe BIM dimensions is that they are additional details or information that are added to a model to help the project team better understand the model (Hamil, 2021) [42]. This is a concrete way to integrate different types of data into an information model. You can get a more accurate picture of your project by adding detailed dimensions such as, how it should be organized, what it costs, and how it should be maintained.

Note that BIM dimensions are different from BIM development levels. BIM dimensions, on the other hand, are details or other information stored in the model, such as cost, time, and other factors.

This article explains what it means to add different data dimensions to your BIM model, how it works in practice, and what benefits you can expect.

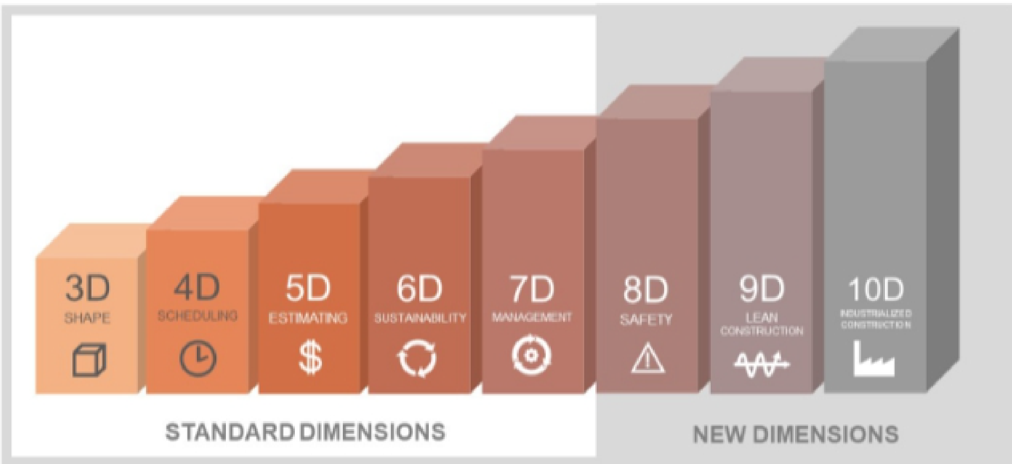


Figure 2.1: Dimensions of BIM

Building Information Modeling (BIM) levels are a way to categorize the maturity and scope of BIM implementation in a construction project or organization. Level is defined by the level of collaboration and information sharing throughout the project lifecycle. The most widely accepted framework for BIM Levels is the British BIM Levels. It classifies BIM into four levels (0-3), each representing a different stage of his BIM implementation and integration.

Figure 2.2: BIM levels

II.5.2 BIM dimensions

II.5.2.1 1D BIM

Refers to the use of BIM technology to represent and manage information related to the linear elements of a building or infrastructure project. This is mainly information about quantities, dimensions, and basic data of linear components such as length, width, height, and other basic parameters (Milestone PLM Solutions) [43].

II.5.2.2 2D BIM

This involves using BIM technology to represent and manage information related to the two-dimensional geometry of building elements. It includes floor plans, elevations, and sections, giving you a more detailed representation of your project compared to 1D BIM (Eastman, C. 2011) [5].

Detailed Documentation: Detailed floor plans, elevations, and sections that are accurate representations of the grid relationship and dimensions of building components can be created in 2D BIM. These drawings are essential documents for the development of design, regulatory approval, and construction implementation (Eastman, C., Teicholz, P., Sacks, R., and Liston, K. 2011) [5].

Coordination and Communication: The 2D BIM enhances coordination and communication between project stakeholders through the centralisation of building data in a digital model. In order to reduce errors and misunderstandings in the construction process, design changes, annotations or markups can be easily shared and monitored (Succar, B. 2009) [8].

Quantity Takeoff and Estimation: Although 2D BIM is mainly focused on geometry, it can simplify the basic process of estimating quantities and taking estimates by linking building elements with metadata such as dimensions, areas or material specifications. This information will be used to estimate and budget for the preliminary costs (Giel, B. 2013) [44].

II.5.2.3 3D BIM

3D BIM is a digital geometric model that represents the X, Y and Z axes linked to other information. 3D modeling tools have been very successful for the following reasons:

- Generate 2D views of geometric information at varying levels of detail from 3D models.
- Create schedules to report on different types of objects in your 3D model.
- Combine multiple 3D models and report geometric inconsistencies.

All of these features greatly increase accuracy and efficiency and reduce the risk of errors in your projects. Additionally, additional benefits arise when specific information is added or linked to these models (Eastman, C., Teicholz, P., Sacks, R., & Liston, K. 2011) [5].

II.5.2.4 4D BIM

4D BIM could add time and schedule information to 3D models (Ocean, n.d.) [9]. 4D BIM models add new information dimensions to the project information model in the form of planning data. This information allows the project team to create a detailed and accurate project plan, keeping in mind the interdependencies of the various tasks (Cards, n.d.) [45]. This data is used to provide reliable project details and a visual representation of project progress over time. This also solves the problem of communication gaps between the construction site team and the planning team (Succar, B. 2009) [8].

II.5.2.5 5D BIM

It's about integrating 3D models and their costs. The core concept of 5D BIM is to extract detailed and accurate cost information for building components. 5D BIM also helps project managers see how changes in materials, design, and areas will not only change the appearance of the building but also impact budget and time (Bryde, D., & Broquetas, M. 2013) [13].

These include different types of costs, such as acquisition costs, installation costs, operating costs, and maintenance costs. These cost calculations can be done from a variety of data sources. Integrating these costs into a 3D model allows construction companies to predict the quantities of different components in a project and relate them to their respective costs to calculate the total cost of the structure (Cards, n.d.) [45].

II.5.2.6 6D BIM

This dimension could add project lifecycle information to the BIM model, such as: Manufacturing, Installation, Operation, Maintenance, and Repair Information. All this information is integrated into his BIM model and handed over to the owner for optimal performance and maintenance (NBS Knowledge (n.d.)) [46]. 6D BIM is not only used at the end of a project, but also facilitates the design phase for users. This helps in the decision-making process to shift the focus from capital expenditure to operational expenditure of the constructed asset (Riley, 2013) [10].

6D BIM, also known as integrated BIM, focuses on sustainability. This serves as a complete model for the customer and includes a kind of manual for the operation and maintenance of the building (Underwood, J., & Isikdag, U. 2009) [7].

II.5.2.7 7D BIM

Is an efficient integration of 3D project management model, 1D schedule management model, and 3D BIM. It is a BIM technology designed to manage project sustainability in construction projects. Complex construction projects can be easily managed, reducing any hurdles (Andreani Marta, 2019) [48].

7D BIM is a new technology that intelligently integrates 3D project management models to make the 7th dimension powerful enough to recognize the sustainability of a project's architectural design. This integration is several levels smarter than incremental sizing.

Helps identify design conflicts, structural changes, 3D project management, miscellaneous equipment installations, maintenance procedures, and other steps to efficiently assist project managers and engineers in complex construction projects (Andreani Marta, B. S. 2019) [48].

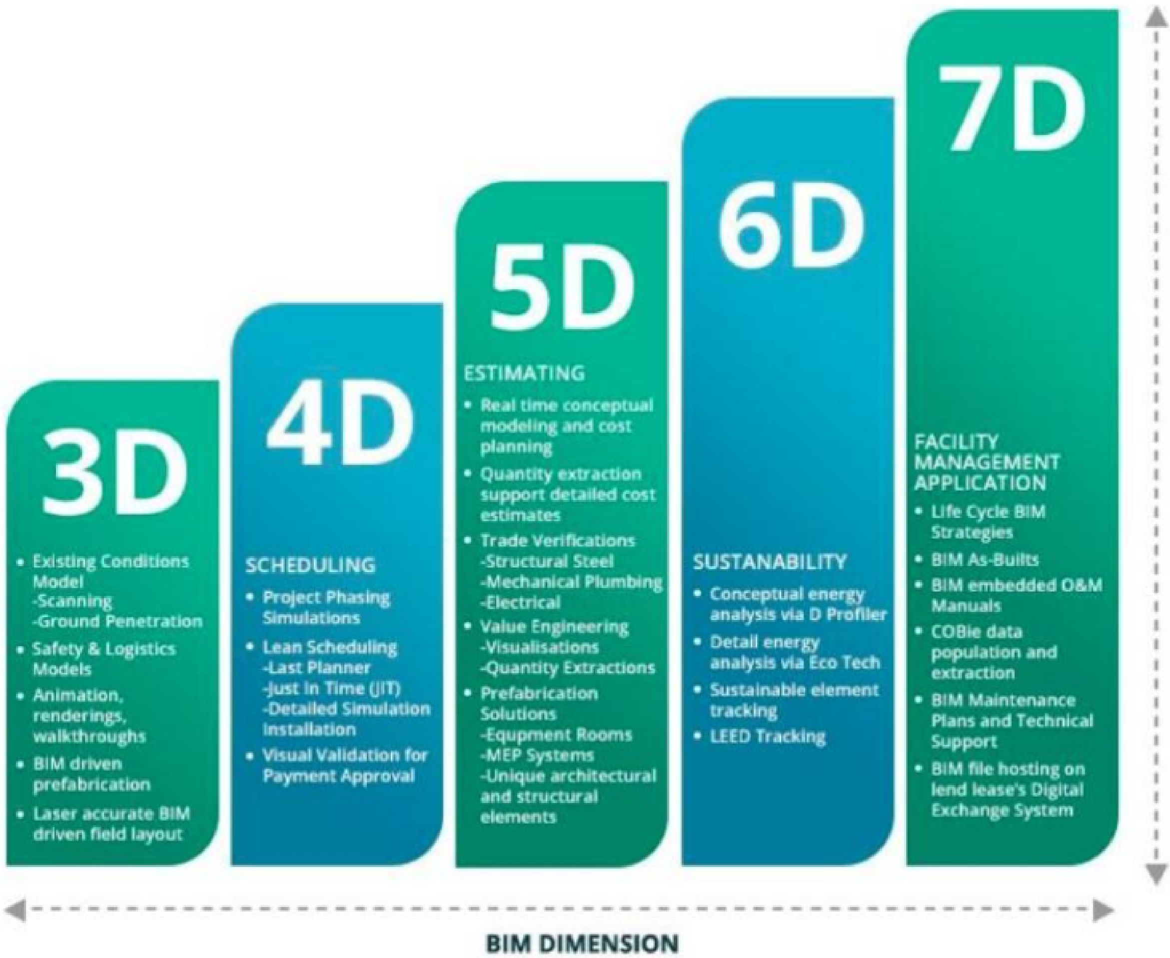


Figure 2.3: Bim different dimensions

II.5.2.8 8D BIM

This dimension focuses on incorporating safety considerations directly into the BIM model during design and construction, permitting proactive identity and mitigation of ability hazards.
This leads to safer work environments and decreased accidents.
It has different aspects such as simulating construction processes to evaluate risks and discover pinch points, designing for higher access, egress, and fall safety measures, and integrating safety data into the model for training and focus purposes (I. Kamardeen) [49].

II.5.2.9 9D BIM

It integrates lean construction principles into the BIM model, aiming to take away waste and optimize techniques for advanced performance and cost delivery. This includes practices like just-in-time material delivery, minimized rework, and use of standardized components.

The different aspects are optimizing material logistics and reducing on-site storage needs, identifying and eliminating non-value-adding activities through process mapping, and designing for modularity and prefabrication to streamline construction (T. Jadhav) [50].

II.5.2.10 10D BIM

This dimension looks beyond individual projects, that specializes in optimizing the complete construction industry through data-driven insights and integration with off-site manufacturing processes. This includes prefabrication, modularization, and mass customization, leveraging economies of scale and automation for faster, more efficient construction.

The aspects for this dimension are standardizing constructing additives and approaches to permit mass production, integrating BIM with off-site manufacturing facilities for seamless workflow, and using information analytics to optimize resource allocation and construction logistics (T. Jadhav) [50].

II.5.3 Levels BIM

II.5.3.1 Level 0 BIM

In Level 0 BIM, there is no collaboration using BIM. Typically, 2D CAD design tools are used and information is exchanged in paper or electronic format. All project participants work independently without a common central digital model (NBS National BIM Report 2017) [51].

II.5.3.2 Level 1 BIM

Level 1 BIM uses 3D CAD tools for design, but that information is not shared in a collaborative environment. Each party maintains its own individual 3D model of her, and information exchange typically occurs via 2D drawings and documents (NBS National BIM Report 2017) [51].

II.5.3.3 Level 2 BIM

Level 2 BIM is characterized by the creation of a common 3D model that is accessible to all parties involved in the project. Common Data Environment (CDE) facilitates collaboration and standardizes information exchange. Level 2 BIM is often associated with the UK's obligation to comply with his BIM Level 2 in government projects (Scottish Futures Trust)[52] .

II.5.3.4 Level 3 BIM

Level 3 BIM involves full collaboration between all parties on a single shared project model. This model does not necessarily need to be stored in a central database, but can be accessed and modified in real time by all parties. Level 3 represents a fully integrated and collaborative BIM environment (NBS National BIM Report 2017) [51].

In summary, the BIM level represents an advanced framework for implementing and integrating Building Information Modeling (BIM) into construction projects. Levels range from 0 to 3 indicate the maturity and scope of BIM implementation, with emphasis on collaboration and information exchange throughout the project lifecycle.

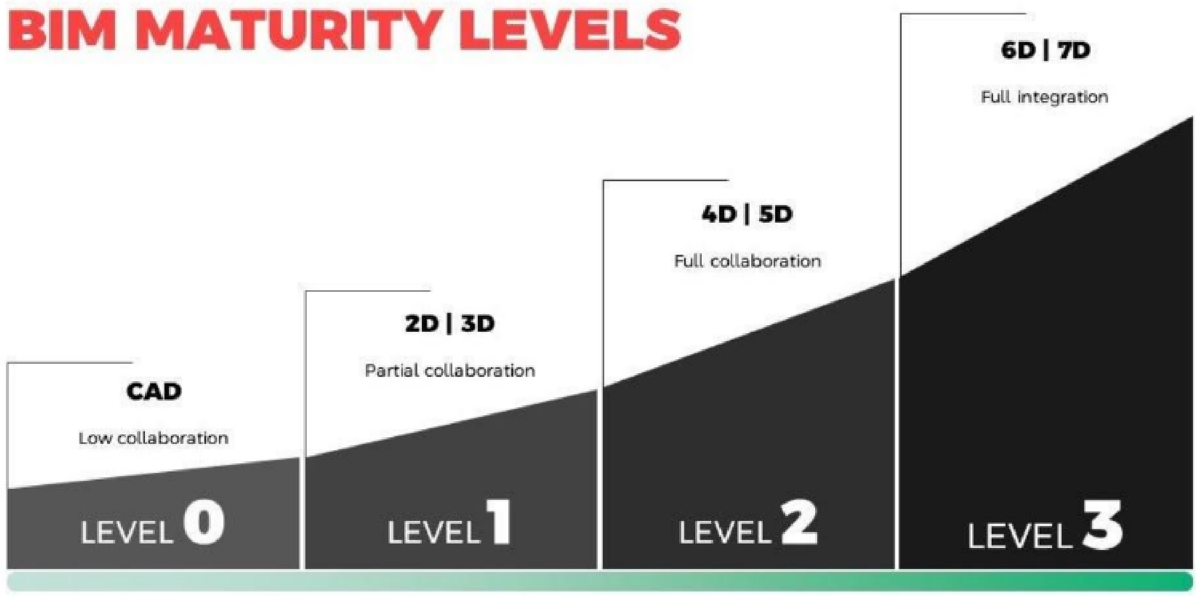


Figure 2.4: BIM maturity levels

II.5.4 Interaction between BIM dimensions and BIM levels

The key interplay among dimensions and degrees is that better BIM levels commonly necessitate incorporating greater dimensions:

- **Basic levels (1-2):** Focus on three-D geometry with constrained extra information.
- **Intermediate levels (2-3):** Start incorporating 4D and 5D facts for scheduling and fee estimation.
- **Advanced levels (3+):** Utilize all dimensions (three-D, 4D, 5D, 6D, 7D) for complete mission management, facility management, and lifecycle analysis (NBS National BIM Report 2017) [51].

Here‘s how the interaction works:

- **Level 1 model:** Primarily 3D, however including particular elements (like doors) with fee facts should flow it closer to 5D.
- **Level 2 model:** Scheduling information for construction phases provides a 4D aspect.
- **Level 3 model:** Integrating with facility control software program for operational data introduces 6D (Fischer, M., & Kunz, J. 2004) [53].

Impact:

- **Greater information:** Each additional dimension enriches the model, permitting collaboration, knowledgeable decision-making, and advanced project outcomes.
- **Level-particular focus:** Each level prioritizes particular dimensions primarily based totally on assignment needs.
- **Flexibility:** Depending on the project stage and requirements, different dimensions can be emphasized inside a selected BIM level (Arayici, Y. 2011) [54].

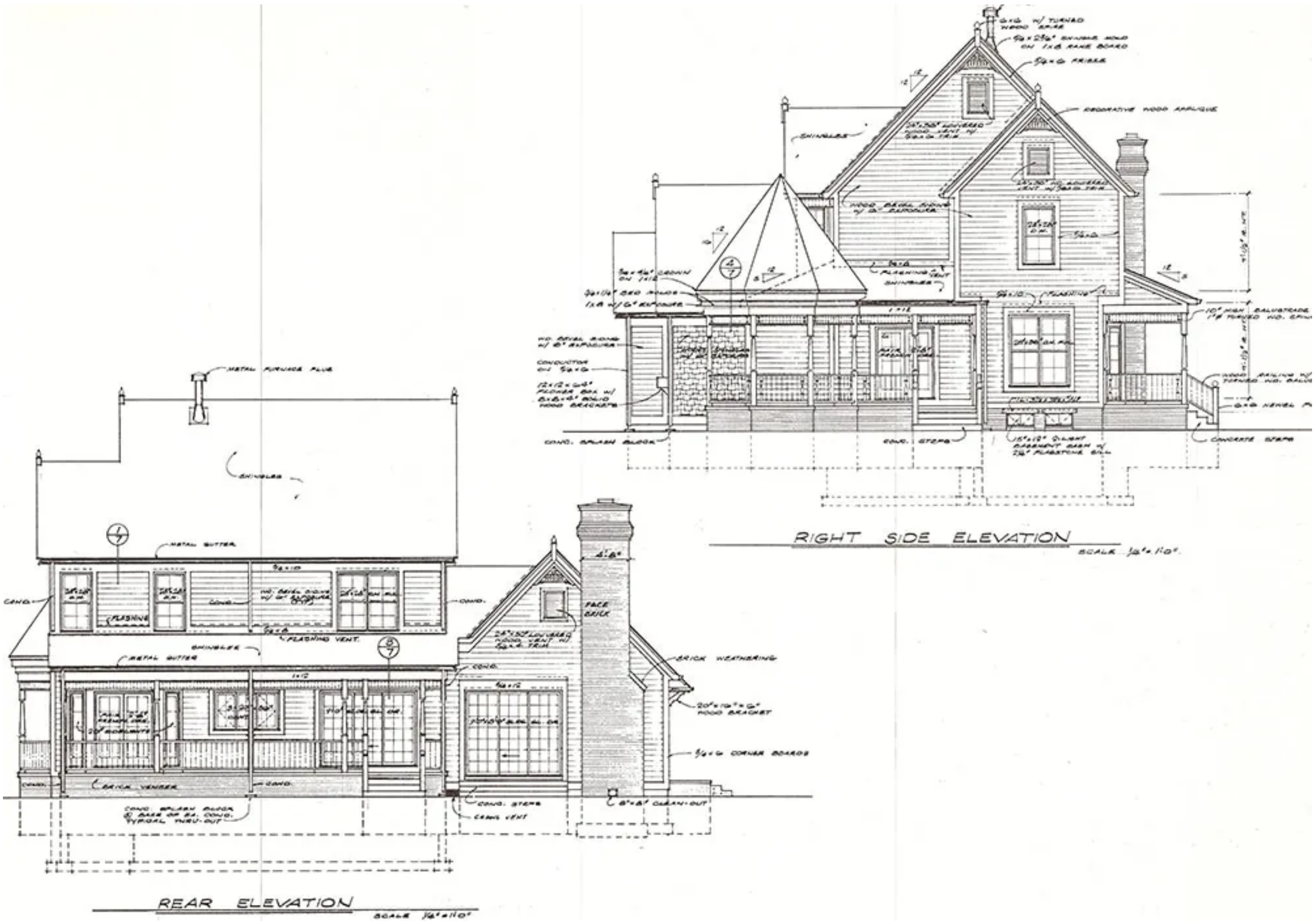


Figure 2.5: Level 0; Low collaboration; No BIM

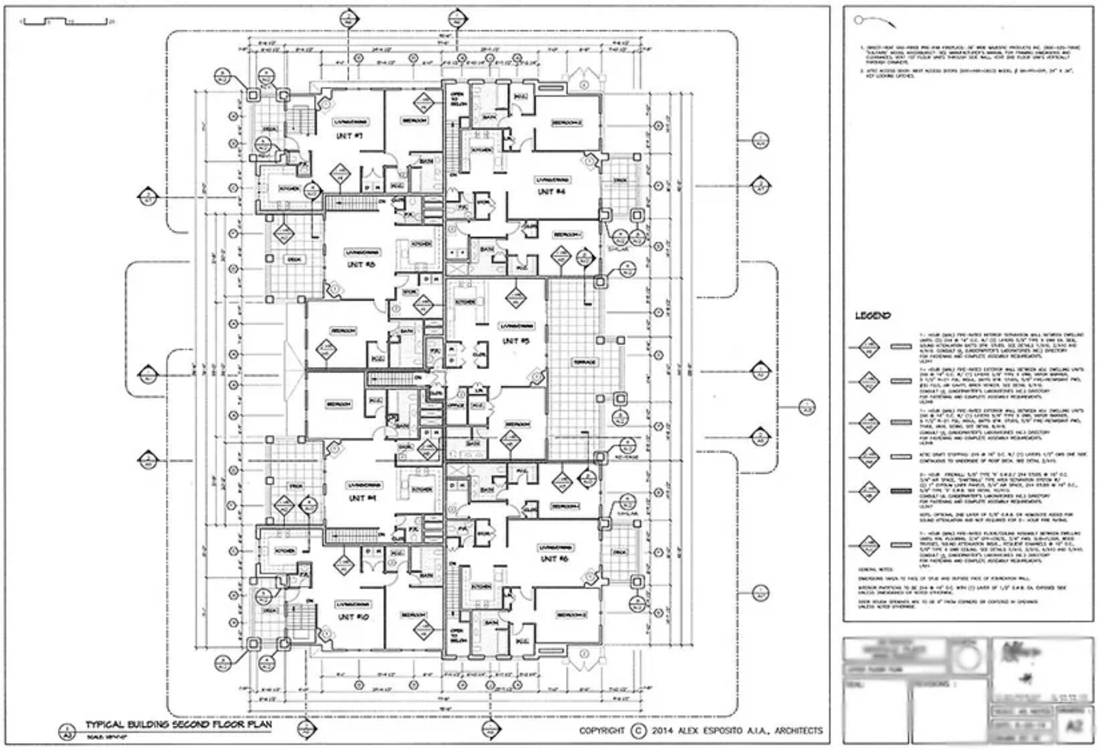


Figure 2.6: Level 1; Partial collaboration; 2D and 3D

Figure 2.7: Level 2; Full collaboration; 3D 4D and 5D

Figure 2.8: Full integration; Integration of 6D and 7D

II.5.5 Outcome

It's important to remember that these dimensions are still evolving and not yet industry standards. However, their capacity for enhancing safety, efficiency, and sustainability in construction is undeniable. As the technology matures and adoption increases, BIM 8D, 9D, and 10D have the potential to revolutionize the manner we design, build, and function buildings (I. Kamardeen [49] & T. Jadhav [50]).

In summary, these dimensions help or facilitate the project team to better visualize the 3D model. Adding 4D BIM allows your team to stay informed of construction progress. 5D BIM allows teams to compare the planned cost of a structure with the actual cost. 6D BIM makes facility management much simpler and less complex. Similarly, 7D BIM allows project teams to manage projects more efficiently (Sacks, R., & Liston, K. 2011) [5].

BIM levels constitute a modern method to information management in construction, offering increasing benefits with every level. They move from fundamental 2D drafting (Level 0) to collaborative, data-rich 3D models (Level 3 and beyond) (BuildingSMART. n.d.) [55].

Overall, BIM levels provide a clear path to advanced assignement effects for both individual disciplines and the construction industry as a whole. The optimal level for you depends on your specific project needs, goals, and resources.

Figure 2.9: BIM dimensions/levels objectives

II.6 BIM Software

II.6.1 Description

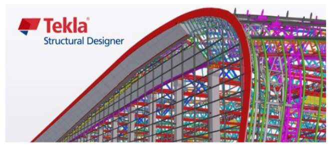
Building Information Modeling (BIM) software plays an important role in the construction industry, allowing professionals to create and manage digital representations of the physical and functional characteristics of buildings and infrastructure (Sacks, R., & Liston, K. (2011)) [5]. Below are some notable BIM software packages and references for further information:

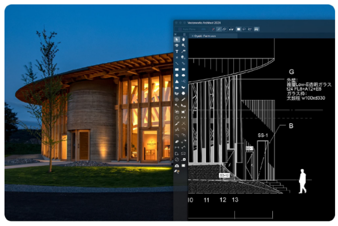
Table 2.1: BIM Softaware

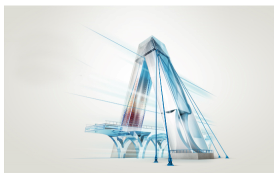
Software	Description	Logo
Autodesk Revit	Autodesk Revit is a widely used BIM software for architects, engineers, and construction professionals. It facilitates collaborative design and documentation (Autodesk. (n.d.)[56]. Revit [57]) **Main Differences:** Revit is known for its strong parametric modeling features, which are especially useful for architectural design and analysis projects. Its compatibility with other Autodesk software like AutoCAD and Navisworks guarantees smooth communication and information sharing, improving teamwork among different fields. Furthermore, Revit provides a wide range of tools for analyzing building performance, enabling users to improve designs in terms of sustainability and energy efficiency. (Autodesk. (n.d.)[56]. Revit [57]) **Similar Points:** Similar to other BIM programs, Revit highlights the significance of 3D modeling, visualization, and data-driven design principles. It enables project teams to collaborate and coordinate by offering a centralized platform for project data and communication. Moreover, Revit facilitates the generation of elaborate construction documentation, aiding in guaranteeing precise and effective project completion. (Autodesk. (n.d.)[56]. Revit [57]) .	

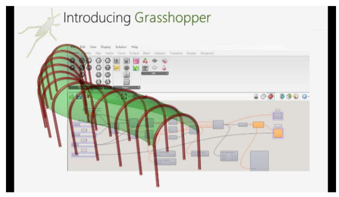
Graphisoft ARCHICAD	ARCHICAD is a BIM software developed by Graphisoft, known for its focus on architectural design and collaboration among team members. (Graphisoft. (n.d.). [58] ARCHICAD). **Main Differences:** ArchiCAD stands out for its user-friendly interface and advanced modeling features, especially for intricate geometry and parametric design. The Virtual Building concept highlights the significance of 3D modeling and visualization in architectural design. Moreover, the compatibility of ArchiCAD with other software platforms and its openBIM strategy make it a flexible option for collaborative projects in various fields. **Similar Points:** ArchiCAD, like other BIM software, emphasizes the importance of collaborating workflows and utilizing data-driven design principles. It acts as a main center for project details and communication, helping to easily coordinate project stakeholders. Furthermore, ArchiCAD enables the development of detailed construction documents, guaranteeing precise and effective project completion.	

Bentley Systems AECOsim Building Designer	AECOsim Building Designer by Bentley Systems offers BIM tools for multidisciplinary collaboration in building design and construction projects (Bentley Systems. (n.d.). AECOsim Building Designer) [59]. **Main Differences:** AECOsim Building Designer is recognized for its ability to work together with other Bentley Systems products like MicroStation and ProjectWise, allowing smooth sharing of data and teamwork between different fields. Its sophisticated analysis features make it appropriate for extensive and intricate projects, providing in-depth understanding of building efficiency and construction viability.(Bentley Systems. (n.d.). AECOsim Building Designer) [59]. **Similar Points:** AECOsim Building Designer is in line with other BIM software by promoting teamwork in project settings and enabling smart choices based on data-driven design methods. It serves as a central hub for project details and communication, facilitating efficient teamwork among project groups. In addition, AECOsim Building Designer helps with the development of thorough construction documentation. (Bentley Systems. (n.d.) .AECOsim Building Designer) [59].	

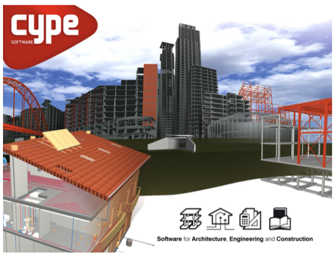
Tekla Structures	Tekla Structures is a BIM software solution for structural engineering, detailing, and construction management, widely used in the construction of steel and concrete structures (Trimble. (n.d.). Tekla Structures) [60]. **Main Differences:** Tekla Structures is notable for its emphasis on structural engineering and detailing, providing advanced features for modeling intricate steel and concrete structures. Its specific features for reinforcing detailing, clash detection, and construction sequencing make it ideal for projects with complex structural needs. Moreover, Tekla Structures easily connects with other software used in construction management, improving cooperation and sharing of data between different areas.(Trimble. (n.d.). Tekla Structures) [60]. **Similar Points:** Tekla Structures aligns with other BIM software by prioritizing teamwork and utilizing data-driven analytics to support smart decision-making. Tekla Structures functions as a centralized hub for project information and communication, enabling smooth collaboration among project participants. (Trimble. (n.d.). Tekla Structures) [60].	

Vectorworks Architect	Vectorworks Architect is a BIM software tailored for architects, providing tools for design, documentation, and collaboration (Vectorworks. (n.d.). Vectorworks Architect) [61]. **Main Differences:** Vectorworks Architect stands out with its emphasis on user-friendly design features and adaptable processes, catering specifically to architects. Architects can efficiently create and refine design ideas using its strong modeling features and wide range of building elements. Moreover, the focus on collaboration and communication tools in Vectorworks Architect improves coordination among project stakeholders, making project delivery more efficient. (Vectorworks. (n.d.). Vectorworks Architect) [61] **Similar Points:** Vectorworks Architect, like many other BIM software, focuses on promoting collaborative design processes and enabling data-driven decision-making. It acts as a centralized hub for project information and communication, facilitating smooth coordination between project teams. Moreover, Vectorworks Architect also enables the development of in-depth construction documentation, guaranteeing precision and productivity during project completion. (Vectorworks. (n.d.). Vectorworks Architect) [61]	 VECTORWORKS ARCHITECT

Dynamo	Dynamo is an open-source visual programming tool that works with BIM software like Revit. It allows users to create custom scripts for design and automation (DynamoBIM. (n.d.). Dynamo) [62]. **Main Differences:** Dynamo's strength lies in its versatility and ability to be customized, enabling users to create personalized solutions to meet precise project needs. Its user-friendly interface and wide range of pre-existing scripts cater to individuals with different programming backgrounds. Moreover, Dynamo's smooth compatibility with other BIM platforms like Revit and Rhino enhances its capabilities and connectivity. (DynamoBIM. (n.d.). Dynamo) [62]. **Similar Points:** Similar to other BIM software, Dynamo enhances teamwork and productivity through simplifying routine tasks and empowering design processes driven by data. Users are able to discover different design options and streamline processes, resulting in increased efficiency and precision when delivering projects (DynamoBIM. (n.d.). Dynamo) [62].	
Allplan	Allplan is a BIM software solution that supports architects and engineers in the design, documentation, and collaboration phases of a construction project (Allplan. (n.d.). Allplan Architecture) [63]. **Main Differences:** Allplan sets itself apart with its parametric modeling features and advanced drawing tools, making it well-suited for architectural design and detailing projects specifically. Its collaboration with Nemetschek's products like SCIA Engineer and Bluebeam Revu improves its features and compatibility, facilitating smooth sharing of data and teamwork among various fields. (Allplan. (n.d.). Allplan Architecture) [63]. **Similar Points:** Just like other BIM software, Allplan prioritizes collaborative design processes and making decisions based on data. It acts as a central platform for project information and communication, enabling project stakeholders to coordinate more easily. (Allplan. (n.d.). Allplan Architecture) [63].	

Trimble SketchUp	While traditionally known for 3D modeling, SketchUp has evolved to support BIM workflows. Trimble offers SketchUp for architects and designers (Trimble. (n.d.). SketchUp)[189]. **Main Differences:** SketchUp stands out thanks to its intuitive interface and easy access, which have made it a top pick for architects and designers when it comes to conceptual design and visualization. Its wide range of pre-made components and plugins improves its functionality, allowing users to simplify design processes and effortlessly experiment with creative ideas. Furthermore, the collaboration and data exchange among project teams is improved by SketchUp's close relationship with other Trimble products like Trimble Connect and SketchUp Viewer. (Trimble. (n.d.). SketchUp)[189]. **Similar Points:** Even though SketchUp has historically emphasized 3D modeling, it shares a dedication with other BIM software in promoting collaborative design methods and utilizing data-driven information. It acts as a central hub for project information and communication, encouraging efficient collaboration among project stakeholders (Trimble. (n.d.). SketchUp)[189].	
Rhino (with Grasshopper)	Rhino, a 3D modeling software, is often used in conjunction with Grasshopper, a visual scripting language, for parametric and algorithmic design within a BIM context (McNeel. (n.d.). [64] Rhino. ; Grasshopper. (n.d.)[190]). **Main Differences:** Rhino is known for its versatility and strong modeling features, enabling users to design complex creations and experiment with creative ideas. Architects and designers in various industries prefer it due to its ability to work with different file formats and software. Grasshopper enhances Rhino by providing a graphical programming platform to create parametric designs and automate recurring tasks. (McNeel. (n.d.). [64] Rhino. ; Grasshopper. (n.d.)[190]). **Similar Points:** Although Rhino and Grasshopper serve different purposes, they align with other BIM software by prioritizing collaborative design processes and utilizing data-driven insights. They play a vital role in the BIM process, enhancing communication and coordination among those involved in the project. (McNeel. (n.d.). [64] Rhino. ; Grasshopper. (n.d.)[190]).	

Synchro PRO	Synchro PRO is a 4D BIM software that integrates 3D models with project schedules, allowing for visualizing construction progress over time (Bentley Systems. (n.d.). Synchro PRO)[193]. **Main Differences:** Synchro PRO sets itself apart by emphasizing 4D visualization, allowing users to simulate and analyze construction sequences in a dynamic and interactive setting. The advanced scheduling features and user-friendly interface are favored by construction planners and project managers looking to streamline project timelines and resource allocation. Furthermore, the integration of Synchro PRO with other Bentley Systems products, including ProjectWise and MicroStation, allows for smooth data exchange and collaboration among project teams. (Bentley Systems. (n.d.). Synchro PRO)[193]. **Similar Points:** Synchro PRO shares common ground with other BIM software in its dedication to promoting collaborative project environments and leveraging data-driven insights for informed decision-making. Serving as a centralized platform for project information and communication, Synchro PRO facilitates seamless coordination among project stakeholders. (Bentley Systems. (n.d.). Synchro PRO)[193].	

AutoCAD Civil 3D	AutoCAD Civil 3D is a BIM software designed for civil engineering and infrastructure projects, including road design and land development (Autodesk. (n.d.). [56] AutoCAD Civil 3D[191]). **Main Differences:** AutoCAD Civil 3D is notable for its specialization in civil engineering and infrastructure projects, providing specific tools for tasks like terrain modeling, road design, and hydraulic analysis. The seamless data exchange and collaboration across project teams are improved by its integration with other Autodesk products like AutoCAD and Revit, enhancing its functionality and interoperability. Moreover, civil engineering professionals prefer AutoCAD Civil 3D due to its support for industry-specific standards and workflows. (Autodesk. (n.d.). [56] AutoCAD Civil 3D[191]) **Similar Points:** Similar to other BIM software, AutoCAD Civil 3D prioritizes collaborative design. It acts as a central hub for project details and communication, making it easier for project stakeholders to coordinate. (Autodesk. (n.d.). [56] AutoCAD Civil 3D[191]).	
CYPE	CYPE provides software solutions for structural engineering,including BIM applications for the analysis and design of structures (CYPE. (n.d.). CYPE Software) [65]. **Main Differences:** CYPE is known for its specialization in structural engineering and its vast array of tools specifically tailored for structural analysis and design. Its BIM tools harmoniously blend with other CYPE software like CYPECAD and CYPE 3D, improving its features and compatibility. (CYPE. (n.d.). CYPE Software) [65]. **Similar Points:** CYPE agrees with other BIM software in its dedication to utilizing insights driven by data. By serving as a centralized hub for project data and communication, CYPE enables smooth collaboration among all involved parties (CYPE. (n.d.). CYPE Software) [65].	

When choosing BIM software, it's important to consider your project's specific needs and workflow. Additionally, the functionality of the Software may evolve over time. Therefore, we recommend checking the official website for the latest information.

II.6.2 Interaction between different software

Interoperability stays a critical project withinside the BIM industry, however there are methods for different BIM software to "talk" to each other:

- Open Standards
  Industry Foundation Classes (IFC): The maximum extensively used open layout for changing BIM data among one-of-a-kind software platforms. While now no longer perfect, it covers numerous factors like geometry, properties, and relationships.

  The Industry Foundation Classes (IFC) are an open data schema created by the International Organization for Standardization (ISO) to enable interoperability between various Building Information Modeling (BIM) software platforms. First introduced in the late 1990s by the International Alliance for Interoperability (IAI), IFC is now the most commonly used standard for exchanging BIM data. BuildingSMART International, a consortium of industry stakeholders, is currently overseeing the development with the goal of enhancing the construction and infrastructure sectors through open standards (BuildingSMART International. (n.d.)[124].
  IFC strives to offer a complete structure for presenting different facets of building information, such as geometric data, characteristics, connections, and other metadata crucial for successful cooperation and information sharing throughout the building's entire lifespan. It provides a consistent and organized structure for storing and exchanging BIM data, allowing for smooth collaboration and compatibility among various software programs utilized by architects, engineers, contractors, and other construction stakeholders(Sacks, R., & Liston, K. 2011)[5].
  Even though IFC is widely used and helpful, it still faces challenges. A notable drawback is its complexity, which may make it challenging for some users to implement and understand. Furthermore, continuous efforts are required to achieve complete interoperability among various software platforms, as differences in understanding and application of the standard may cause compatibility problems between different systems(Giel, B., & Fischer, M. 2008)[181].

  BCF: Designed for changing problems and feedback associated with BIM models, permitting collaboration throughout tools (Eastman, C., Teicholz, 2011) [5].

- Native File Formats
  Some software program permits constrained import/export of local files, though data loss is frequently possible.
  Plugins and translators might also additionally enhance compatibility, but interoperability isn't guaranteed (Succar, B. (2009)) [8].

- Cloud-based Platforms
  Platforms like BIM 360 permit importing and viewing models in various formats, facilitating a few collaborations.
  Data extraction for calculations or simulations may still require conversion with ability losses (Succar, B. (2009)) [8].

- APIs and SDKs
  Advanced customers can leverage Application Programming Interfaces (APIs) or Software Development Kits (SDKs) for deeper integration among tools.
  Requires programming understanding and isn't with ease handy to everyone (Yezioro, A., & Dori, D. 2017) [66].

- Interoperability Services
  Companies provide paid offerings to convert models among formats, validate IFC data, and enhance interoperability.
  Can address complex needs but adds cost and potential delays (Sacks, R., & Liston, K. 2011) [5].

Figure 2.10: BIM software

II.7 Lean and VSM concepts

Lean and Value Stream Mapping (VSM) are important concepts in project management and production, with key connections to Building Information Modeling (BIM) in construction and architecture.

II.7.1 Lean concept

Lean is a management approach based on the Toyota Production System (TPS) that aims to reduce waste and increase value.

The fundamental principles of Lean consist of:

- Value: Grasping the significance of value from the viewpoint of the customer.
- Value Stream: Recognizing every stage in the value stream and eliminating unnecessary actions.
- Flow: Making sure that the value-producing processes continue without any disruptions.
- Pull: Creating products based on customer demand to minimize excessive production.
- Perfection: Aiming for ongoing enhancement.

Lean focuses on increasing customer value by streamlining processes, enhancing quality, and minimizing expenses and timeframes (Womack, J. P., & Jones, D. T. 2003)[147].

Figure 2.11: Lean management

II.7.2 VSM concept

The main principales are:
Value Stream Mapping (VSM): VSM is a Lean tool that helps to display and study the movement of materials and information needed to deliver a product or service to a customer. VSM aids in pinpointing inefficiencies and areas for enhancement within a process. Important stages in VSM consist of: ‘

- Mapping the Current State: Making a visual depiction of the present procedure.
- Identifying Waste: Drawing attention to areas where waste occurs.
- Designing the Future State: Establishing an efficient process map.
- Implementing Changes: Implementing enhancements and consistently monitoring the outcomes.

VSM works well in complicated settings with various processes and stakeholders, like in construction projects (Rother, M., & Shook, J. 1999)[179].

Figure 2.12: VSM process

II.7.3 Lean, VSM and BIM connection

Relationship Between Lean, VSM, and BIM: Combining Lean, VSM, and BIM in construction can improve project efficiency and effectiveness synergistically. Here is how they are connected:

- Lean Principles in BIM: Implementing lean principles in the BIM process enhances efficiency, reduces inefficiencies, and boosts project results. BIM's information-rich setting aids Lean efforts by offering accurate data necessary for waste identification and removal (Azhar, S. 2011)[142].
- VSM and BIM Integration: VSM has the capability to evaluate and enhance the BIM process. By outlining the BIM process, individuals involved can pinpoint inefficiencies and incorporate Lean enhancements. On the other hand, BIM tools can improve VSM by offering precise data and visual representations, simplifying the comprehension and communication of present and future state procedures (Martin, K., & Osterling, M. 2014)[180].

II.8 BIM standards

II.8.1 Foreword

ISO 19650 is a set of standards for managing information throughout the lifecycle of a building through the use of building information modeling. The ISO 19650 standard series now comprises five parts, with parts 1 and 2 being the most relevant for enterprise BIM. Part 1 (ISO, 2018c) [67] introduces the concepts and principles of BIM information management.
Part 2 (ISO, 2018d)[68] specifies information management standards during the delivery phase.

Part 3 (ISO, 2020f)[69] provides the criteria for the information and collaboration environment during the plant's operational phase, impacting digital practices applicable to individual projects as well as the company's overall digital approach. This part also allows for the administration of assets added by users of assets while they are in use.

Part 4 (ISO, 2022)[70] is in the works, but the goal is to provide decision-making processes and criteria for information exchange.

Part 5 (ISO, 2020b)[71] emphasizes the importance of developing a security-centric approach to information management. However, a more complementary framework is required to meet all areas of supporting information security and business BIM security requirements.

ISO 19650, for example, provides a standard framework for collaboration, communication, requirements, information exchange, and management across all actors performing all leadership positions in the asset value chain. Furthermore, the standard includes recommended concepts and principles for information management and business processes in the entire built environment and seeks to enable information management throughout the asset lifecycle (ISO, 2018c) [67].

The adaptable, role-based ISO 19650 series of standards can be modified to manage assets and asset users, as well as building projects of any size and complexity (ANZGuide, 2019)[72]. In addition to ISO 19650, there are other prospective and existing international standards aimed at improving the quality of AECOO(Architecture, Engineering, Construction, Operations, and Owner) and other industries' goods, processes, and information.

For example, the introduction of the ISO 9000 series (ISO, 2015a[73], ISO, 2015b[74]) has greatly aided in the organization of quality-related data in construction, and ISO 19650 aligns with other adjacent standards such as the ISO 9000 series, and the ISO 9000 series clarifies the relationship between the ISO 55000 series (ISO, 2014a[75], ISO, 2014b[76]).

The ISO 21500 series standardizes descriptions of concepts and processes deemed best practices for project management in AECOO (ISO, 2012[77]). The ISO 55000 series standardizes AM. ISO 8000 (ISO, 2018a)[78] standardizes construction data quality (ISO, 2018a[78], ISO, 27000, information security management standards (ISO, 2018f[79], ISO, 2013a[80], ISO, 2013b[81]), and ISO 31000 (ISO, 2018e)[82]. AECOO has produced risk management recommendations (ISO, 2018e)[82].

ISO 21597 (ISO, 2020c[83], ISO, 2020d[84]) defines the notion of an information container as one that organizes data drops of digital construction information based on linked data (including heterogeneous data from any domain in any format that adheres to linked data principles). ISO 16739 (ISO, 2018b)[85] defines a conceptual data schema based on Industry Foundation Classes (IFC). ISO 19650 defined the "Level of Information Needs" (LOIN). Nonetheless, we are glad that another of his LOIN standards is currently being developed, including a "data specification schema" (EN 17412-3) to make LOIN machine-readable (CEN, 2020). This LOIN standard is related to EN ISO 23387 (Data Templates) (ISO, 2020f) [69], and the modification makes it less tied to IFC and more open to implementations such as semantic solutions.

EN ISO 23387's next version intends to define the essential standard words and definitions, including LOIN. It is expected that future updates of the linked data standards prEN 17632 and EN ISO 12006-3 (IFD) (ISO, 2007)[86] would work in concert with it. Furthermore, the ISO 14000 series (ISO, 2015c)[87] establishes environmental management systems aimed at enhancing construction businesses' environmental performance.

Some of the standards mentioned above have had a substantial impact on industrial practice. We chose the ISO 19650 series for this document because it is particularly focused on increasing the interface between design, engineering, and additive manufacturing. This is due to the fact that most standards focus on other areas of the project lifecycle, unintentionally disrupting the flow of information. The adoption of open standardized formats, for example, is quite good, and ISO 16739 (ISO, 2018b)[85] is now the foundation for open standardized exchanges.

In business BIM, however, IFC is just one of many ISO requirements that must be met during both the delivery and operation phases. Furthermore, in order to handle bespoke digital twins, IoT, sensors, and real-time data, information systems must be adaptable, and interoperable, and assure data quality and security. Furthermore, the solution should be simple to identify, scalable, and profitable. ISO 23386 (ISO, 2020e)[88] and ISO 23387 (ISO, 2020f)[69] are closely related to the EXPRESS language in the present edition.

II.8.2 Interconnection of ISO Standards

ISO 19650: This standard is concerned with the organizationn and digitisation of information on buildings and civil engineering works, including building modeling data. It provides guidance on how to manage information throughout the lifecycle of a built asset, BIM(ISO 19650) [89].

ISO 9000: ISO 9000 is a series of standards that outline principles of quality management systems (QMS). The principles of ISO 9000 may be used by organizations in the architecture, engineering, construction, operation and ownershipAECOO industry to guarantee quality processes and outputs although they are not directly associated with building or asset management (California's Manufacturing Network).

ISO 55000: Asset management practices are standardized by this standard series. ISO 55000 provides guidance on how to effectively manage their assets throughout the organisation's lifecycle, aligning the management of assets with organizational objectives and maximizing value (ISO/TC 251)[90].

ISO 21500: it is a guideline for managing projects. It offers advice on ideas and procedures linked to project management, which is essential in the AECOO sector for efficiently completing construction projects on schedule, within financial constraints, and meeting quality criteria (ISO 21500:2021) [110].

ISO 8000: it is centered on the management of data quality. It establishes the rules and methods to guarantee the quality of data utilized in organizations. In construction, ISO 8000 is used to guarantee construction data is accurate, complete, and consistent, crucial for making informed decisions and delivering projects effectively (ISO 8000:2014)[103].

ISO 21597: This standard deals with the categorization of data within the construction sector. It offers a structure for arranging and classifying construction-related data, enhancing communication, collaboration, and information management in construction projects (Rasmussen et al., 2017)[91].

ISO 16739 (IFC): Also referred to as Industry Foundation Classes (IFC), this is a standardized format for transmitting and distributing building information models (BIM) data among various software systems. It enables smooth exchange of information between various BIM software applications, promoting interoperability among stakeholders during the project lifecycle (Fahad, M., Bus, N. & Fies, B. Semantic)[92].

ISO 23387: Concentrates on incorporating sustainability into the procurement procedure. It offers recommendations for organizations to take into account environmental, social, and economic aspects when purchasing goods and services, such as construction projects. Incorporating sustainability into procurement processes is consistent with overall sustainability objectives and can result in construction practices that are more environmentally and socially responsible (Hartley, R.V.L. 1928)[93].

These standards all share the common goal of enhancing processes, quality, and results in the AECOO sector. They may differ in their specific areas of focus, such as information management, quality management, project management, asset management, data quality, classification, interoperability, and sustainability. Collectively, they create a thorough structure to improve efficiency, effectiveness, and sustainability in different areas of construction and asset management (Magdalena Ordyniec, M M.Sc).

II.8.3 Central Concepts

However, future upgrades to these standards will address Product Data Templates (PDTs) without linking them to the Building Smart Data Dictionary (bsDD). As a result, BsDD may obstruct the integration of all important AM parts. The Enterprise BIM principles given in Section 4 of this document are designed to provide an information infrastructure for the interchange of updated information based on Semantic Web technologies, hence ISO 19650 series upgrades are regarded valuable. Some of the principles in ISO 19650 serve to future-proof company BIM concepts and boost their international applicability.

II.8.3.1 Asset Information Model

The Asset Information Model (AIM) is a key idea in ISO 19650, illustrating the digital representation of a built asset's physical and functional attributes. It covers a range of data types - geometric, alphanumeric, and graphical - to offer a thorough understanding of the asset from start to finish. The AIM functions as a main storage of data that assists decision-making, design, construction, operation, and maintenance activities (ISO 19650-2:2018, Part 2)[109].

II.8.3.2 Level of Information Need

The idea of Level of Information Need (LOIN) in ISO 19650 pertains to the distinct information requirements during various project or asset lifecycle phases. It acknowledges that stakeholders have different information requirements based on their positions, duties, and the stage of the project. LOIN makes sure the appropriate amount of detail and information is given to offer support for decision-making, minimize risk, and optimize project delivery delivery (ISO 19650-1:2018, Part 1)[95].

II.8.3.3 Concepts development

The three most central concepts of ISO 19650 are AM, LOIN, and CDE.

- AM: ISO 19650 integrates facility management (FM) with asset management (AM) ideas. Although FM and AM are distinct disciplines, both are concerned with the management of physical assets and services in the built environment. Furthermore, AM and FM have established a recommended terminology standard and language (ISO, 2018c) [67]. However, as digitalization progressed, the clear distinction between AM and FM faded, and new opportunities developed in the form of integrated solutions that bridged the gap between the two. In the future, Digital Information Management, a leadership role (agreed upon) applied to different buildings, will take over his FM and AM responsibilities.

- LOIN: The ISO 19650 series provides a consistent methodology for describing and employing the purpose-driven notion of the Information Needs Level (LOIN) in conjunction with information delivery via Building Information Modeling (BIM) (ISO, 2018c [67], ISO, 2018d[68], ISO, 2020f)[69]. Depending on the phase, context of usage, and timing, the LOIN Principles establish the range and required level of geometric, alphanumeric, and document quality, quantity, and granularity to support various work performance and professional tasks. ISO, 2018c [67]; Borrmann et al., 2018; ISO, 2018d[68]; ISO, 2020f[69]; ABAB, 2018). The appointee determines how her LOIN will be defined as part of the project's information standard (delivery phase) or asset information standard (operation phase).

  The new domain adds features of object detail, dimension, location, appearance, and parametric behavior to meet the geometric portion of these criteria and satisfy information needs (ISO, 2020f)[69]. All of this guarantees that the varied information requirements are based on the information required for the various roles in the operational process. Furthermore, the LOIN principles are bolstered by the establishment of his own LOIN standard series (CEN, 2020). The justification for the successful and profitable usage of BIM in ISO 19650 is that LOIN is defined based on the purposes and reasons for which information is required for each information delivery (ISO, 2018c) [67]. This necessitates a high level of proficiency in each individual position. Containers that communicate information with delivery milestones should be developed based on one or more information requirements defined per purpose utilizing the LOIN framework (Bolpagni and Hooper, 2021)[97].
  LOIN can be calculated using a variety of criteria or scores. For example, in terms of quality, quantity, and granularity, two complimentary but independent criteria can identify geometric and alphabetic content. A LOIN strategy of this type is critical to the successful exchange of information for all information given (work orders at all levels). Anyone who performs anything in a building is an end user, even professionals who lack knowledge of information, communication, and technology (ICT) or BIM.
  These various end-user categories should be considered in your information requirements. Figure 1 is the result of merging all of the LOIN principle's objectives. To make this happen, a custom collaboration solution (CDE) is required. The numerous milestones are numbered below to highlight the most important questions and factors to consider. This goal-driven method asks what, what, how, and who requires each piece of information.

- CDE: Adoption of the Common Data Environment (CDE), or, more accurately, the CDE ecosystem concept, is another fundamental notion in ISO 19650. "A common data environment (CDE) is a single source of information used to collect, manage, and distribute

documents, graphical models, and non-graphical data across project teams,", According to the BIM Wiki. "Creating this single source of truth facilitates collaboration between project team members and avoids duplication and errors."
A shared data environment, in other words, is a digital hub where information is collected as part of a conventional BIM process. In reality, it was created and popularized as part of his BIM Level 2 standard in the United Kingdom. CDE may store and manage construction project information. For enterprises aiming to exploit digital asset data, reliable and steady information flow, addressing the information needs of established roles, and effective information management are critical.

CDE promotes the transparent and predictable flow of information across organizational boundaries, assisted by information technology. At the same time, ISO 19650 highlights the need for all parties involved to have a clear awareness of their duties and the entire information management process along the asset value chain (ANZGuide, 2019)[72]. Furthermore, the ISO 19650 series of standards promotes sustainability in information interchange throughout the asset lifecycle (ANZGuide, 2019)[72]. Simultaneously, we contribute to environmental, social, and economic sustainability by offering standardized e-purchase information processes, such as tracking and recording of e-purchase information utilized in asset items.

The ISO 19650 series of standards was developed based on international expert consensus and represents the first version suitable for the development of best practices and standardization processes, as well as for BIM-based information management, including exchange and recording, and provides a comprehensive framework for, version control, and organization for all actors at all stages of the asset value chain (ISO, 2018c) [67].

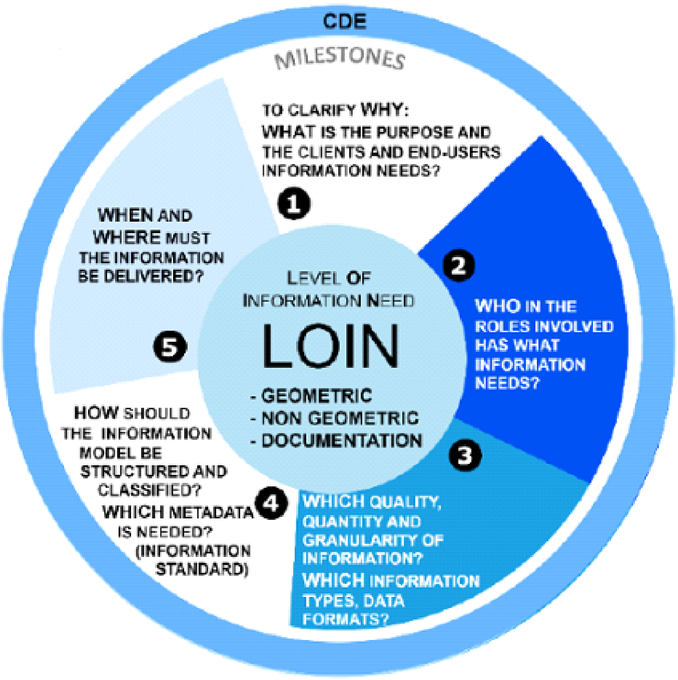


Figure 2.13: Aspects of managing the collaborative production of information using the LOIN principles and a CDE, developed with inspiration from (ANZGuide 2019)[72].

II.8.4 Common Data Environment

The CDE is a platform that enables collaborative management and sharing of project information following ISO 19650 standards. It acts as a safe storage space where stakeholders can retrieve, edit, and share important information, files, and designs during the project's duration. The CDE improves communication, coordination, and transparency among project participants, thereby improving efficiency and reducing errors (BS EN ISO 19650-5:2020, Part 5)[96].

On the left, you'll find a simplified representation of how team members normally discuss project information. It's a massive matrix, and getting the correct information to the right people at the right moment is difficult. Information is frequently stored in multiple systems. Because information interchange is manual, it is prone to errors, which can be costly.

On the right side, the project team embraced her CDE. With CDE, information flows through a central repository, making it easier to administer and more up-to-date. CDE is a mechanism for controlling the flow of information. This guarantees that construction documents (as well as other information such as markings and issues) are only delivered to project team members once they have been reviewed, approved, and released for their intended purpose.

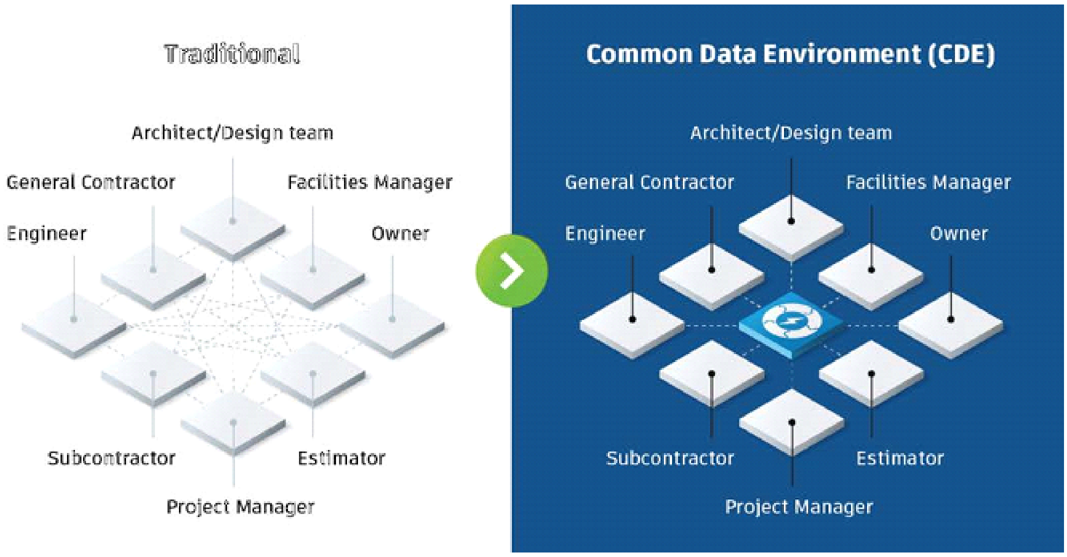


Figure 2.14: Traditional information flow versus common data environment

Figure 2.14 compares a conventional project information flow to a project information flow that includes a Common Data Environment (CDE) implementation.

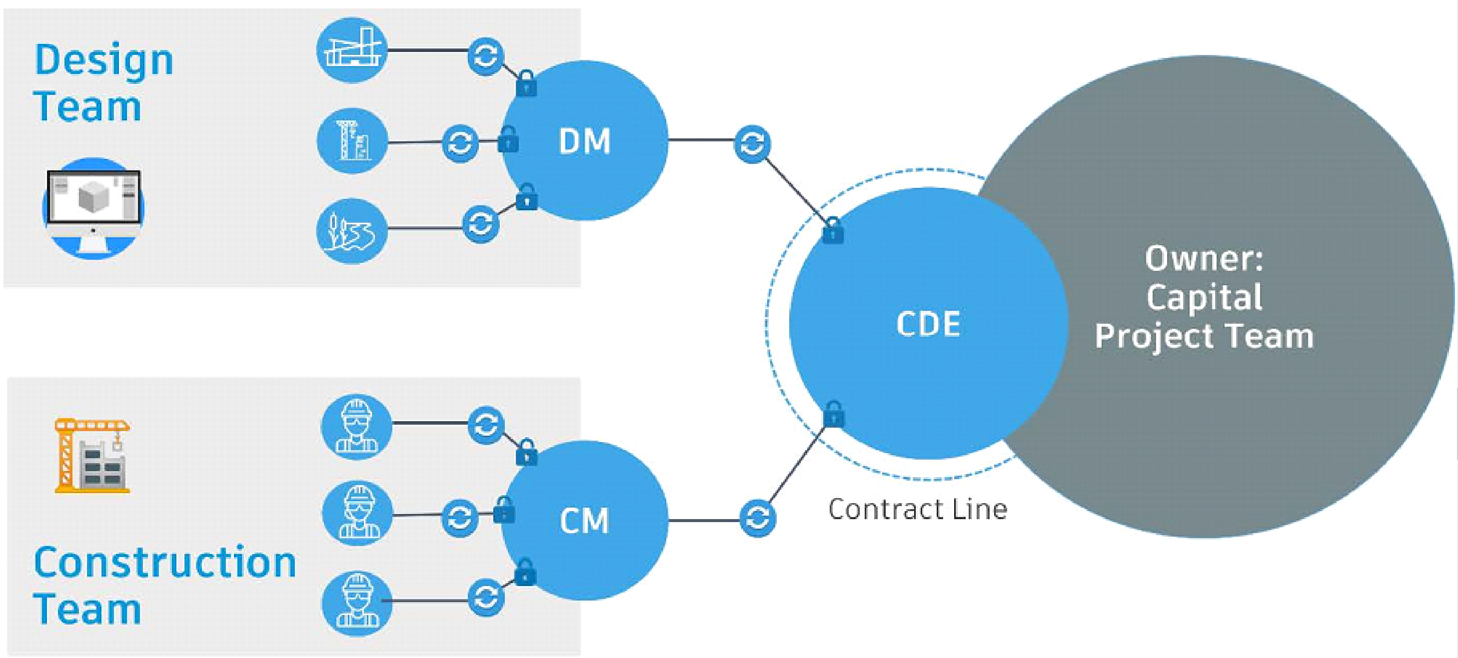


Figure 2.15: Project team organization

Figure 2.15 depicts a typical project delivery configuration, which represents the ecosystem of businesses that must collaborate to design, implement, and run construction and infrastructure projects. However, there are other obstacles to overcome, including:

- Contractual divisions between disciplines and teams
- The design and construction teams, as well as the complete supply chain, are separate entities that must regulate the interchange and access to project data and information.

A project's core information hub is vital not just for the team but also for the owner. Without it, information might become untrustworthy, increasing project risk (ISO. (2018). ISO 19650-1:2018, Part 1)[95].

II.8.4.1 Benefits of a Common Data Environment

Improved cooperation: When used effectively, digital technology has been shown time and again to improve collaboration. This means that all project data and information must flow into and be updated in a central system. This enhances cooperation and teamwork within your organization as well as across teams (British Standards Institution. 2013)[98].

Make a single source of truth: Never underestimate the importance of having a single source of truth for your project. A trusted location where team members can access real-time plans, modifications, and data leads to better decisions and insights across projects and even across the firm.

Increased productivity and quality: By eliminating the need to manually regenerate data, a shared data environment eliminates input errors and information loss. This implies that the entire firm now has better access to information, and teams can make choices more quickly (Construction Industry Council. 2018)[99].

Risk mitigation: CDE reduces risk by increasing transparency and insight into the overall project status. This allows for continuous improvement and predictability over time, which is important for a company's continued development.

Increased security: CDE provides administrators and IT professionals with greater control over their data and information, increasing security (ISO. (2018). ISO 19650-1:2018, Part 1)[95].

II.8.4.2 CDE IMPACTS

User experience is a key aspect of a shared data environment. It must be simple to use in order to be effective. This means that it is simple to use and takes little or no training for your employees to become acquainted with the system.

Accessible: Because information is stored in the cloud, it is available to everyone who needs it, whether they are in the office or on a building site (with the right permissions, of course).

Integration: CDE must integrate with your existing systems and processes. The idea is to break down silos and promote collaboration generally.

Standardization and Scalability: CDE should allow you to standardize procedures and processes across projects, and it should be scalable for projects of any size and complexity.

Secure: To preserve data integrity and manage access to sensitive and proprietary information, shared data environments must be secure (ISO. (2018). ISO 19650-1:2018, Part 1)[95].

II.8.4.3 Autodesk BIM 360 CDE RELATED TO ISO 19650

Autodesk BIM 360 is a common data environment (CDE) that supports the following:

- Permission control
- Audit trail
- Document control and versioning
- Custom metadata
- Integrated with design workflows
- Design and office file viewing
- 2D and 3D viewing and compare
- Approval workflow
- Transmittals
- Markups and issue management
- Mobile access
- Reporting and analytics

- Support for unique file naming*
- Support for file naming standards*
- Revision and status*
- Enhanced review and approval workflows*

*At the moment, a limited beta version is available.
(Autodesk. (n.d.). BIM 360 Overview)[100].

II.9 Chapter conclusion

In conclusion, this review of literature has thoroughly examined different aspects of Building Information Modeling (BIM) and how it has developed over time. We have observed how the architecture, engineering, and construction (AEC) industry has been altered by the innovative approach of BIM through an overview of general ideas and historical progression. The versatility and potential of BIM for enhancing project outcomes through improved collaboration, efficiency, and accuracy have been underscored by its integration with various areas (Eastman, C., Teicholz, P., Sacks, R., & Liston, K. 2011)[5].

In addition, there has been a discussion about using BIM in projects, highlighting the tactics and difficulties linked to its use. The examination of BIM dimensions and levels has led to a greater comprehension of the maturity and complexity of BIM usage, demonstrating the importance of various dimensions in enhancing project management and implementation (Hardin, B., & McCool, D. 2015)[167].

Research into BIM software has shown the diverse range of tools offered, each designed with specific features to address various requirements in the BIM environment (Azhar, S. 2011). Finally, the conversation surrounding BIM standards, specifically the ISO 19650 series, has emphasized the significance of standardized procedures and structures in ensuring uniformity and compatibility in BIM projects (ISO 19650-1[2]; ISO 19650-2[109]).

As the AEC industry progresses, the significance of BIM is expected to grow, fueled by technological advancements and rising requests for sustainable and efficient construction methods. This review of literature prepares for more research on the particular effects and upcoming changes of BIM, which will be important in influencing the construction industry (Azhar, S. 2011)[142].

Chapter III

ISO 19650 Parts 1 and 2

III.1 ISO 19650 – Part 1 (Concepts and Principles)

III.1.1 Prelude

This document presents recommended concepts for business processes across the construction sector to support the management and generation of information throughout the lifecycle of construction assets (referred to as 'information management') using Building Information Modeling (BIM). and the principles. These processes provide asset owners/operators, customers, their supply chains, and those involved in project financing with opportunities, increased opportunities, reduced risks, reduced costs, etc. through the creation and use of asset and project information models. Can deliver positive business outcomes. In this document, the verb form "should" be used to express recommendations.

The referenced file is primarily intended for use by those involved in the procurement, design, construction and/or commissioning of built assets and those involved in delivering asset management activities, including operations and maintenance.

It applies to build facilities and construction projects of any size and complexity. This includes large tracts of land, infrastructure networks, individual buildings and pieces of infrastructure, as well as the projects and project groups that deliver them. However, the concepts and principles contained in this document must be applied in a manner that is proportionate and appropriate to the size and complexity of the asset or project. This tendency is especially noticeable when small and medium-sized enterprises are mainly entrusted with asset management and project execution. It is also important to integrate the procurement and mobilization of assets and project personnel into existing technology procurement and mobilization processes as much as possible.

The concepts and principles contained in this document are intended for everyone involved in the asset lifecycle. These include, but are not limited to, asset owners/operators, customers, asset managers, design teams, construction teams, equipment manufacturers, technical experts, regulators, investors, insurers, and end-user.

There are many ways in which asset owners/operators or customers can meet their specific needs and best respond to national circumstances. This includes procurement channels and reservation arrangements. The information management concepts and principles described in this document should be adopted and applied according to the specific circumstances and requirements of asset management or project delivery activities. The information requirements should specify or guide how this is to be achieved and the details need to be agreed in a timely manner so that the requirements are met efficiently and effectively.

Efficient delivery and operation of assets requires cooperation between those involved in construction projects and asset management. Organizations are increasingly working in new collaborative environments to achieve higher levels of quality and better reuse existing knowledge and experience. A key outcome of these collaborative environments is the ability to communicate, reuse, and share information more efficiently, potentially reducing the risk of loss, inconsistency, or misunderstanding.

True collaboration requires mutual understanding and trust, as well as a deeper level of standardized processes than usual, to ensure that information is produced and available in a consistent and timely manner. Information requirements must be passed down the supply chain to the point where the information can be most efficiently generated and collected upon return. Currently, many resources are spent remediating unstructured information.

Resolving issues arising from mismanagement of information by untrained personnel, disorganized efforts by delivery teams, and resolving issues related to information reuse and duplication. These delays can be reduced by adopting the concepts and principles in this document.

In order to improve future editions of the ISO 19650 series, national asset owners, public contracting authorities and authorities are encouraged to collect information and experience regarding their implementation and use.

The ISO 19650 series can benefit from formal asset management processes such as the ISO 55000 series. The ISO 19650 series can also benefit from a systematic approach to quality within an organization, like for example ISO 9001, but ISO 9001 certification is not a requirement of the ISO 19650 series. Additional standards related to information structure and delivery methods are also listed in the bibliography.

Origins of BIM Standards: The development of ISO 19650 can be traced back to the early In the early 2000s, the need for standardised processes and protocols for the implementation of the BIM was recognised by different countries and organisations. Efforts to standardize BIM practices were initiated by organizations such as buildingSMART International, the International Alliance for Interoperability (IAI), and national standards bodies (BuildingSMART International. 2020)[124].

International Standardization Efforts: ISO 19650 was launched by the International Organization for Standardization in response to the growing global adoption of BIM and the need for harmonized standards. The standard was developed by ISO Technical Committee 59/Subcommittee 13 (ISO/TC 59/SC 13), which focuses on the standardization of construction processes and interoperability of information (International Organization for Standardization. (2018). ISO 19650-1:2018)[95].

Publication and adoption: ISO 19650 has been published in two parts, Part 1 for 2018 and Part 2 for 2019. Guidelines for the organization and digitization of information related to buildings and civil engineering works using BIM are laid down in this Standard. It outlines concepts, principles, and processes for information management throughout the asset lifecycle, from inception to decommissioning (International Organization for Standardization. (2019). ISO 19650-2:2018) [109].

III.1.2 Range

This document describes the concepts and principles of information management in the maturity stage called Building Information Modeling (BIM) according to the ISO 19650 series.

It also provides recommendations for an information management framework, including sharing, recording, versioning, and organization for all stakeholders.

In addition, it applies throughout the life cycle of each constructed asset, including strategic planning, initial design, construction, development, documentation and construction, daily operations, maintenance, rehabilitation, repairs, and end of life.

This paper can be adapted to assets or projects of any size and complexity without compromising the flexibility and versatility that characterizes a wide range of potential procurement strategies, and to reduce the cost of implementing this document.

III.1.3 Asset and project information, perspectives and collaborative working

The main pillars underpinning the efficient implementation of Building Information Management systems, including asset and project information management, a wide range of perspectives on the construction ecosystem as well as an essential role for collaboration working methods will be explored throughout this section. We have identified the details of each aspect through a rigorous examination and analysis, giving us an insight into their significance in fostering efficiency, transparency, and innovation within the built environment. By elucidating these fundamental elements, we The aim shall be to provide a holistic picture of the multidisciplinary environment in which BIM is adopted and its profound impact on the construction industry.

- **Asset information**
  Refers to facts associated with the bodily and purposeful traits of the constructed environment. This consists of records of approximately person constructing components, systems, materials, and equipment. Asset records in BIM fashions lets in stakeholders to recognize the specifications, performance, and renovation necessities of every asset inside a project.

- **Project information**
  Encompasses statistics applicable to the whole task lifestyles cycle, from conceptualization to operation. This consists of task timelines, budgets, stakeholder facts, regulatory requirements, and documentation associated with layout and construction. Project facts in BIM give a holistic view of the task and aid decision-making at diverse stages.

- **Perspectives**
  In BIM, "perspectives" generally refers back to the numerous perspectives and representations of the version that stakeholders can get admission to primarily based totally on their roles and needs. Different challenge participants, which include architects, engineers, contractors, facility managers, and owners, can also additionally have particular views tailor-made to their requirements. These views permit customers to cognizance of applicable elements of the version without being beaten via way of means of useless information.

- **Collaborative working**
  Involves the energetic participation and coordination of a couple of stakeholders during the assignment lifestyles cycle. BIM helps collaboration through offering a centralized platform for sharing, updating, and having access to assignment facts in real time.

III.1.4 Definition of information requirements and resulting information models

Organizational Information Requirements (OIR), Asset Information Requirements (AIR), Project Information Requirements (PIR), Employers Information Requirements (EIR), Asset Information Model (AIM), and Project Information Model (PIM) are key additives withinside the realm of Building Information Modelling (BIM). Collectively, they shape a dependent framework that publications the statistics control system in the course of the existence cycle of a creation project.

In conclusion, the dependent development from OIR to AIR, PIR, EIR, AIM, and PIM establishes a clean framework for facts control in BIM. This method guarantees alignment with organizational and assignment goals, helps collaboration, and helps knowledgeable decision-making at some point in the lifestyle cycle of each development assignment and the ensuing asset or facility. By defining facts and necessities at every stage, BIM will become an effective device for optimizing efficiency, lowering errors, and improving the general achievement of creation endeavors.

Table 3.1: Description of Requirements

Additives	Description
OIR	OIR outlines the overarching information needs and objectives of an organization.
AIR	AIR translates these organizational requirements into specific information requirements for managing individual assets throughout their lifecycle.
PIR	PIR specifies the information needs and deliverables for a particular construction project. It serves as a bridge between the project's objectives and the detailed information required for its successful execution.
EIR	EIR sets out the information requirements for a construction project, typically provided by the client or employer. It defines the scope, format, and level of detail for information exchange, ensuring alignment with project objectives.
AIM	AIM is a digital representation of an asset that integrates various data and information throughout its lifecycle. It serves as a central repository for asset information, enabling stakeholders to access and manage data efficiently.
PIM	PIM is a digital representation of a construction project that encompasses design, construction, and operational data. It facilitates collaboration and decision-making among project stakeholders by providing a shared platform for information exchange and coordination.

III.1.5 The information delivery cycle (IDC)

The information delivery cycle withinside the context of the "Organization and Digitization of data approximately buildings and civil engineering works" represents a transformative and systematic technique for coping with statistics throughout the lifestyle cycle of production projects. This cycle entails the strategic organization, digitalization, and powerful usage of data to optimize decision-making, collaboration, and performance.

Specific examples in the IDC connecting with a Revit model: Design Phase: the Revit model can be used to: Develop and share design concepts with project stakeholders through visualizations and simulations.

Automate tasks like generating schedules and quantities, improving design accuracy and efficiency.

Construction Phase: The information-rich 3D model from Revit can be used by: General contractors for creating construction plans and sequencing workflows based on the model.

By emphasizing the business enterprise and digitization of facts associated with homes and civil engineering works, this cycle brings approximately huge improvements in efficiency, collaboration, and usual mission success.

In conclusion, the IDC embodies a modern method to handling records withinside the realm of buildings and civil engineering works. The strategic agency and digitization of records create a basis for collaboration and sustained achievement in an enterprise that is an increasing number of embracing the benefits of virtual transformation. Embracing this cycle positions companies at the forefront of enterprise advancements, unlocking new opportunities for efficiency, sustainability, and excellence in production projects.

Figure 3.1: Generic project and asset information management life cycle

Key

A start of the delivery phase – transfer of relevant information from AIM to PIM

B progressive development of the design intent model into the virtual construction model

C end of delivery phase – transfer of relevant information from PIM to AIM

III.1.6 Project and asset information management functions

This file identifies the kinds of statistics control capabilities that must be taken into consideration and their responsibilities and must be studied along with different appointment documentation. Information management functions, duty and authority must be allotted to events on the idea in their appropriateness and cap potential to carry out them. In smaller corporations or projects, more than one capability can be executed with the aid of using an identical person or party.

Information management functions have to know no longer confer with layout responsibilities. However, for smaller or much less complicated belongings or projects, facts control features can be accomplished along different features inclusive of asset control, assignment control, layout group management, or production management.

It is important not to confuse functions and responsibilities with job titles or with professional or other designations.

III.1.7 Delivery team capability and capacity

Capability refers to being capable of carrying out a given activity, for instance through having important experience, talent or technical resources. Capacity refers to having the ability to finish an activity withinside the required time.

In this point, we can talk about the methodology of value stream mapping with an example:

During the current state mapping one among the activities is Capacity Planning: This activity involves estimating the workload for the team and ensuring they have enough resources (time, manpower) to complete tasks on schedule. Inaccurate capacity planning can lead to delays in subsequent activities.

During the future state mapping one among the improvement strategies is Standardized Work Procedures: Develop standardized work procedures for masonry construction tasks, improving efficiency and reducing rework due to errors.

When a new appointment is made all through a framework settlement or comparable long-time period arrangement, then the scope of the evaluation can be decreased to simply the applicable factors of capability and capacity.

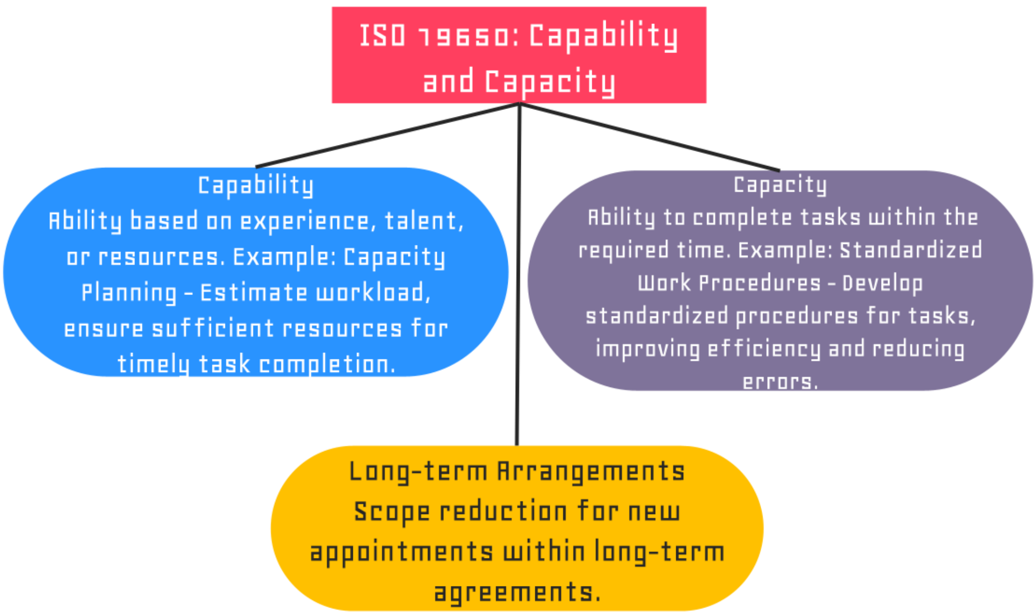


Figure 3.2: Delivery team capability and capacity

III.1.8 Information container-based collaborative working

Container-based collaborative working basically means two things:

The principle that the author or originator of a piece of data, for example a model or a drawing, is responsible and liable for the content and quality still applies. Certain rules about the processes of information management are described in order that information and data may be exchanged in a stable and efficient way.

The collaborative manufacturing of information has to be described in fashionable phrases of dependent facts to permit the essential ideas of facts container-based collaborative running to be achieved.

III.1.9 Information delivery planning

Planning for information delivery is the responsibility of each lead appointed party and appointed party. Plans should be formulated in response to the information requirements set out by the appointing party and should reflect the scope of the appointment within the overall asset life cycle.

At least some of the planning for information delivery should be carried out by the lead appointed party or appointed party before the appointment, as this should form part of the review carried out by the appointing party. More detailed planning can then be required after the appointment is made as part of mobilization. Additional information delivery planning should take place if changes are made to the information requirements or to the delivery team.

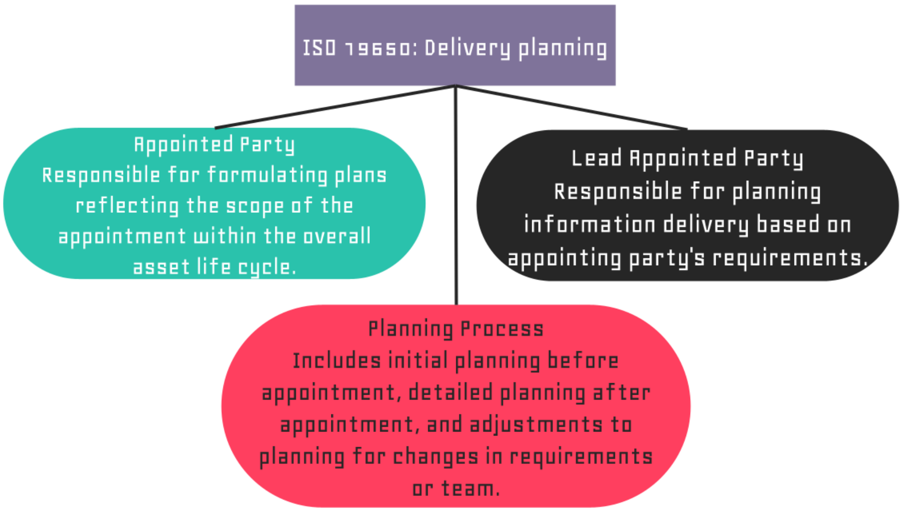


Figure 3.3: Information delivery planning

III.1.10 Common Data Environment (CDE) solution and workflow

A CDE solution and workflow should be used for managing information during asset management and project delivery. During the delivery phase, the CDE solution and workflow support the information management processes in ISO 19650-2:2018, 5.6 and 5.7.

At the end of a project, information containers required for asset management should be moved from the PIM to the AIM. The remaining project information containers, including any in the archived state, should be retained as read-only in case of dispute and to help lessons to be learned. The timescale for retaining project information containers should be defined in the EIR.

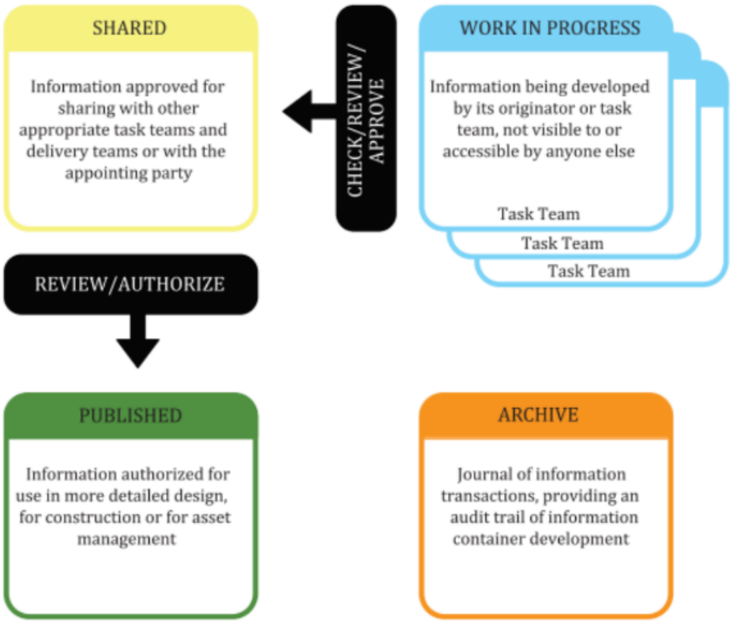


Figure 3.4: CDE concept

Regarding our project with this point we can indicate the Revit integration with CDE. Highlight the importance of seamless data exchange between Revit and the CDE solution.
This ensures the 3D model with its rich data becomes a central component of the project information within the CDE.

Even with value stream mapping, CDE added an importance. For example, in the communication and collaboration activity (without CDE), Communication regarding execution and project updates often occurs through orally or phone calls. This is a time-consuming and prone to misunderstandings.

With CDE (future state mapping) it was an improvement. Streamlined Communication: The CDE platform facilitates communication through discussion forums, document markups, and task management tools.
We reduced errors and rework due to readily available and up-to-date information.

III.1.11 Summary of "BIM according to the ISO 19650"

In summary, ISO 19650 is a series of standards that explain the management of information using Building Information Modeling (BIM). The series consists of five parts that cover different phases of the asset lifecycle, including planning, design, construction, operation, and maintenance. Each part of the series provides recommendations for defining an information management framework, consisting of exchange, recording, model control, and organization. ISO 19650 may be implemented to all types and sizes of assets and by all types of organizations involved in the construction and management of buildings and different constructed belongings.

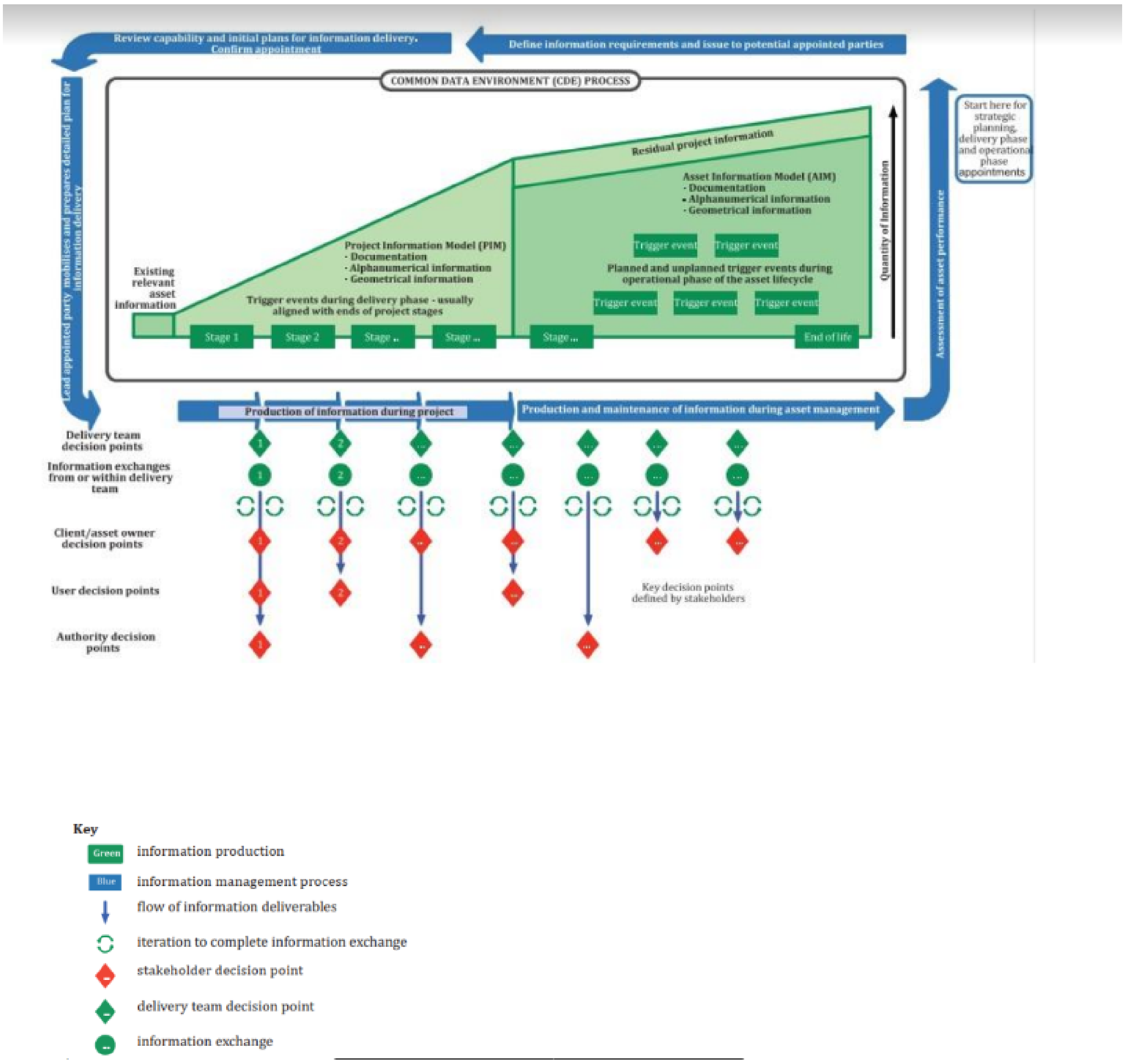


Figure 3.5: Overview and illustration of the information management process

III.1.12 Information transmission

In the area of information transmission, effective coordination and collaboration in building design and construction is built on an interplay between architectural, structural, mechanical, electrica,l or plumbing MEP systems. The integration of these elements into the Building Information Model framework, as shown in the following figure, provides a smooth data exchange and enhances communication between interested parties to projects. The importance of a comprehensive approach to information is illustrated by this synergy. Management, as advocated by authors such as (Eastman et al. 2011)[5], and (Succar (2009))[8], in order to optimize project outcomes and foster efficiency throughout the construction lifecycle.

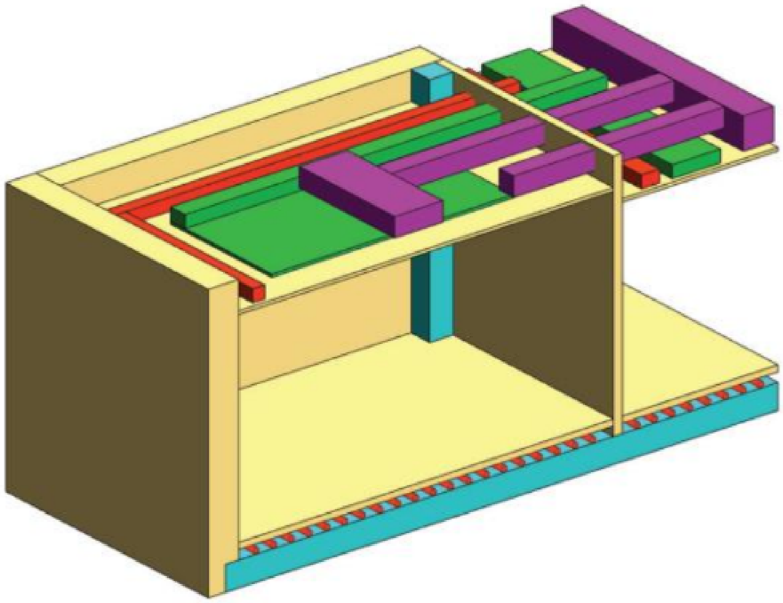


Figure 3.6: Illustration of spatial federation strategy by discipline in a building project

Key

- Yellow: Architecture
- Blue: Structure
- Green, red, purple: Mechanical, electrical and plumbing systems

In conclusion, the powerful transmission of information among architecture, structure, and MEP systems stands as a cornerstone withinside the modernization of the development industry. The synergy accomplished through interdisciplinary collaboration complements the quality, efficiency, and sustainability of constructed environments. By fostering a cohesive flow of records, stakeholders can conquer challenges, optimize designs, and supply initiatives that seamlessly combine architectural aesthetics with structural integrity and functional MEP systems.

III.2 ISO 19650 – Part 2 (Delivery phase of the assets)

III.2.1 Prelude

This document enables appointees to define their information needs at the asset delivery stage and provides an appropriate commercial and collaborative environment in which appointees (multiple appointees) can produce information in an effective and efficient manner.

It applies to build facilities and construction projects of any size and complexity. This includes large real estate properties, infrastructure networks, individual buildings and pieces of infrastructure, and the projects and programs that deliver them. However, the requirements contained in this document must be applied in a manner that is proportionate and appropriate to the size and complexity of the asset or project. In particular, the procurement and mobilization of actors involved in an asset or project should be integrated as much as possible into a documented technology procurement and mobilization process.

Throughout this document, the word "shall have regard to" is used frequently, particularly in the requirements of clause 5. This expression is used to introduce a list of points that individuals should carefully consider in relation to the key requirements set out in Section 5 Mandatory Provisions. The level of consideration involved, the time required for completion, and the need for supporting evidence will vary depending on the complexity of the project, the experience of the parties involved, and the requirements of individual citizens.

Building Information Modeling implementation policy, for relatively small or simple projects, you may be able to complete some of these "to-be-considered" items quickly or discard them as irrelevant.

One way to determine which "should consider" statements are relevant is to review each statement and create templates for projects of varying size and complexity. This document can be used by any appointing party. If the appointee intends to apply this document to the asset (project), this must be reflected in the appointment.

This paper defines the information management process and includes activities that enable delivery teams to collaborate to create information and minimize wasteful activities.

This sheet is primarily intended for use by the following: those involved in the management or production of information during the delivery phase of assets, those involved in the definition and procurement of construction projects, those involved in the specification of appointments and facilitation of collaborative working, those involved in the design, construction, operation, maintenance and decommissioning of assets and those responsible for the realization of value for their organization from their asset base.

This document sets out the requirements related to information management during the handover phase of construction assets and should be reviewed and revised regularly until best practices are established.

III.2.2 Relationship with other standards

The concepts and principles relevant to the application of the requirements in this document are contained in ISO 19650-1 [2].

General information on asset management can be found in ISO 55000[123].

The appointing party may need to consider the concepts and principles contained in both.

ISO 19650-1 [2] and ISO 55000 can support the implementation of the requirements described in this document and the development of asset management within your organization.

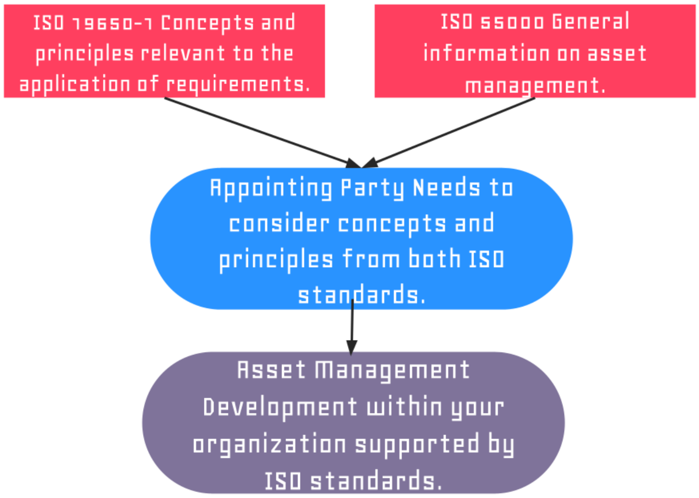


Figure 3.7: ISO Standards and Information Delivery Plannin

III.2.3 Benefits of the ISO 19650 series

The purpose of this series is to help all stakeholders achieve their business goals through the effective and efficient capture, use, and management of information during the asset delivery phase.

Revit with ISO 19650 is a complementary couple, they can explain each other in a different way.

Enhanced Efficiency and Productivity: Standardized workflows and information exchange promoted by ISO 19650, coupled with the use of Revit models, streamline project processes. This improves efficiency and reduces project delivery time.

Using VSM from the last point, we improved communication and collaboration between design and construction teams reduce misunderstandings and missing details.

Through international collaboration in the development of these documents, common information management processes have been identified that can be applied to the most diverse assets in the most diverse organizations, the most diverse cultures, and the most diverse appointment channels.

III.2.4 Range

This document specifies information management requirements in the form of a management process in the context of the asset handover phase and information exchange within this phase using building information modeling.

This sheet is applicable to all types of assets and organizations of all types and sizes, regardless of the procurement strategy is chosen.

III.2.5 Normative references

The following documents are referenced in this text in such a way that their contents constitute all or part of the requirements of this document. For dated references, only the edition cited applies. For undated references, the most recent version of the referenced document (including any changes) applies.

ISO 19650-1 [2], Organization of information about construction works — Information management using building information modeling — Part 1:Concepts and Principles ISO 12006-2, Building construction — Organization of information about construction works — Part 2: Framework for classification

III.2.6 Information management during the delivery phase of assets

Figure 3.8 depicts the information management process which must be implemented during the delivery. Phase is required for every appointment, no matter what stage the project is in.

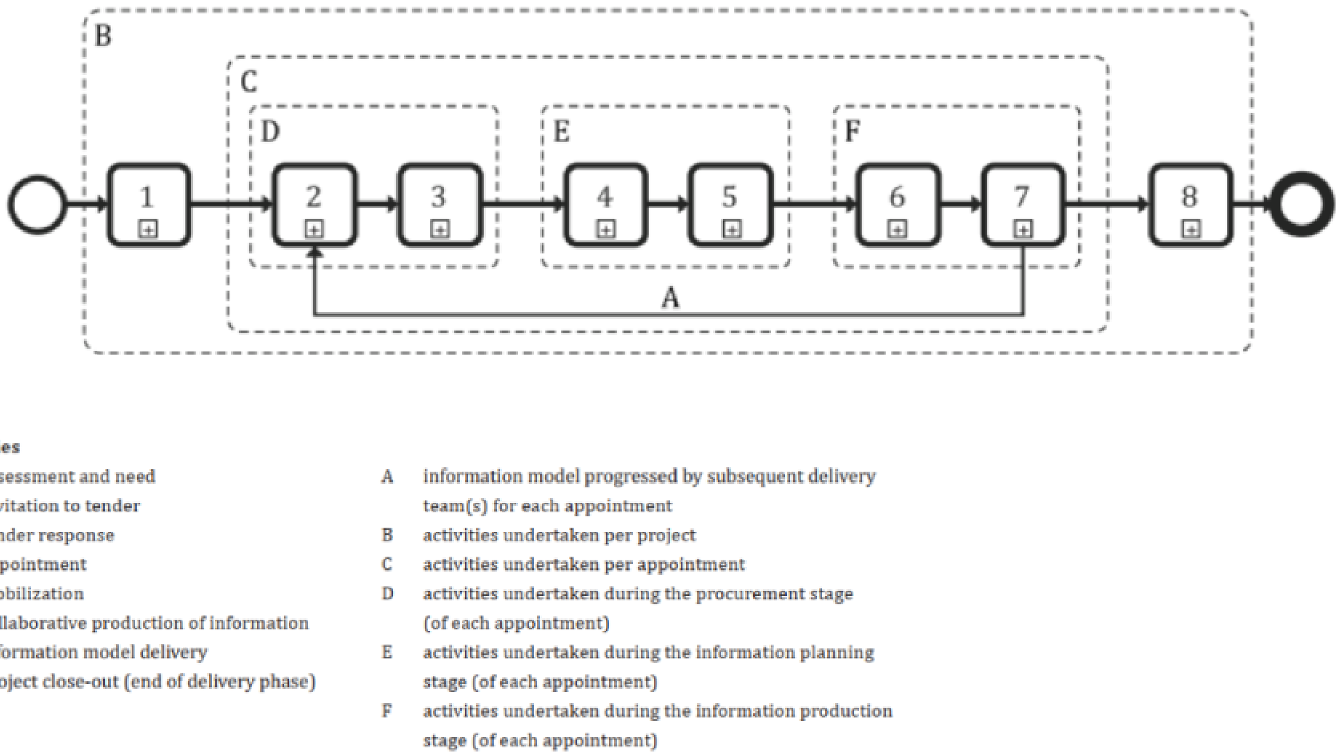


Figure 3.8: Information management during the delivery phase of assets

III.2.7 Information management process during the delivery phase of assets

It is important to mention that the information management process in ISO 19650-2 assumes that the Appointing Party's Organisational and Asset Information Requirements (OIR/AIR) are already defined. At the same time, the process focuses on information delivery, placing most of the responsibility upon the Appointing Party (the client or owner).

This is a pivotal and transformative level withinside the lifestyles cycle of construction projects. This procedure marks the transition from task cognizance to asset utilization, annoying a strategic technique to record enterprise and digitization.

Through the strategic organization and digitization of information, this section guarantees a smooth transition from project completion to effective asset utilization. The meticulous management of digital data not only enhances operational efficiency but also lays the foundation for sustained performance, maintenance, and flexibility in the course of the asset's life cycle.

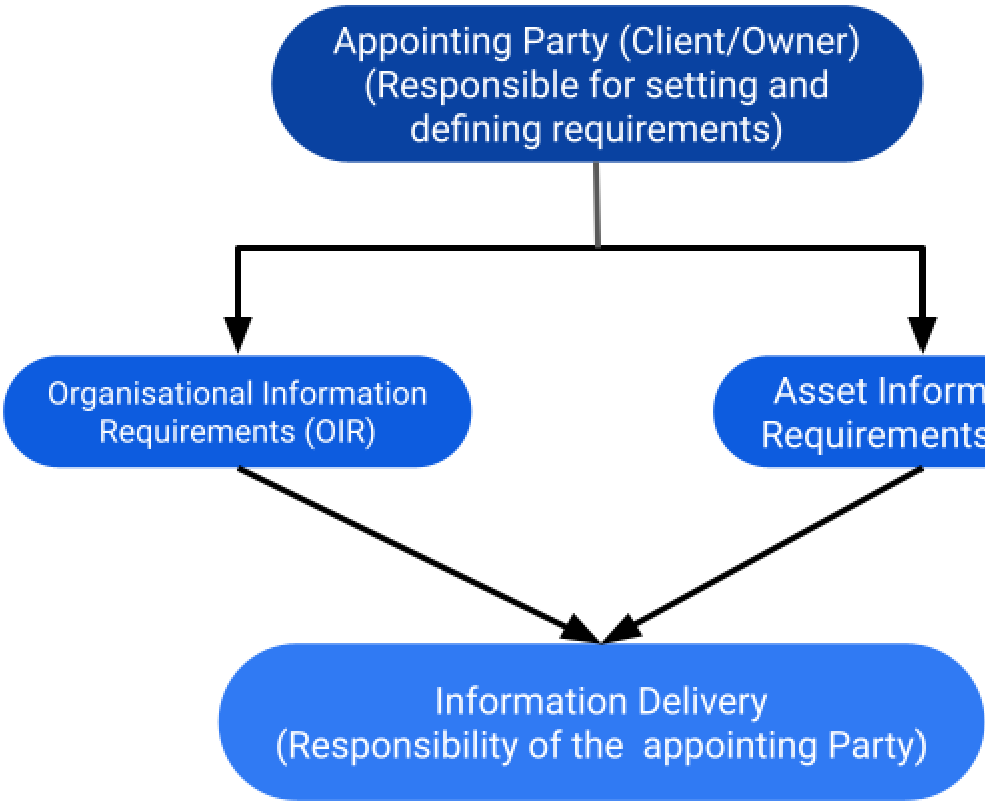
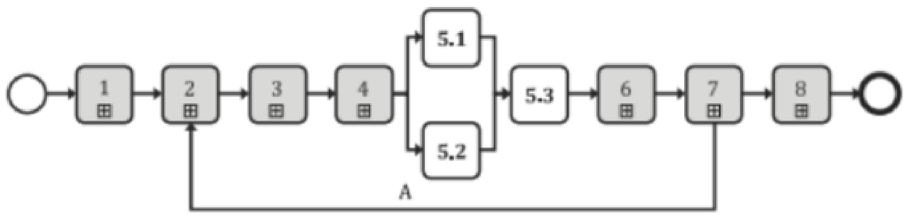


Figure 3.9: Information management process during the delivery phase of assets

Information management process – Mobilization

Mobilization, as a crucial phase in the lifecycle of construction projects, underscores the significance of Information Management in setting the stage for success. Through strategic organization and digitization, this section empowers project stakeholders with a robust foundation of information essential for the initiation and execution of building and civil engineering works. The emphasis on virtual readiness and organized data not only streamline project commencement but also establish a trajectory for effective collaboration, decision-making, and ordinary mission efficiency.



Key

5.1 mobilize resources

5.2 mobilize information technology

5.3 test the project's information production methods and procedures

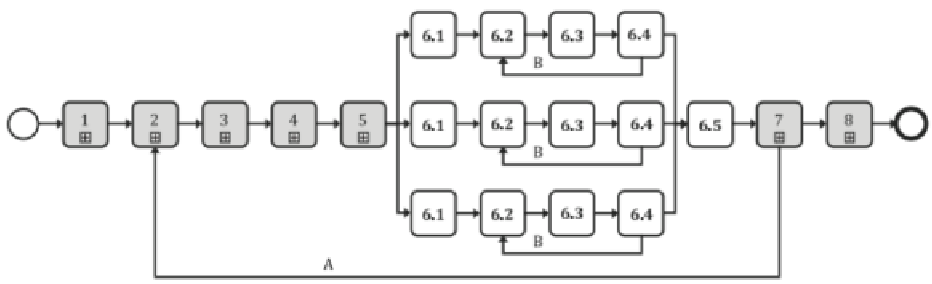
A information model progressed by subsequent delivery team(s) for each appointment

NOTE Activities shown in parallel are to highlight that these activities can be undertaken concurrently.

Figure 3.10: Information management process – Mobilization

III.2.8 Collaborative production of information

Through strategic organization and digitization, this technique fosters effective communication, interdisciplinary collaboration, and streamlined workflows throughout the entire life cycle of buildings and civil engineering works. By embracing a culture of collaboration, stakeholders create a digital ecosystem that not only optimizes project delivery but also paves the manner for a resilient and revolutionary destiny withinside the production landscape.



Key

6.1 check availability of reference information and shared resources

6.2 generate information

6.3 complete quality assurance check

6.4 review information and approve for sharing

6.5 information model review

A information model progressed by subsequent delivery team(s) for each appointment

B new information container revision

Figure 3.11: Collaborative production of information

III.2.9 Information model delivery

The delivery of an Information Model stands as a testament to the progressive shift towards a digitally-enabled and prepared technique withinside the construction industry. By strategically combining the concepts of organization and digitization, this method produces a robust digital representation that transcends traditional documentation. The Information Model becomes a dynamic and living asset, providing stakeholders with a comprehensive view of the built environment. As a useful device for decision-making, collaboration, and optimization, Information Model delivery not only enhances project delivery but also establishes a foundation for a future-ready and interconnected construction landscape.

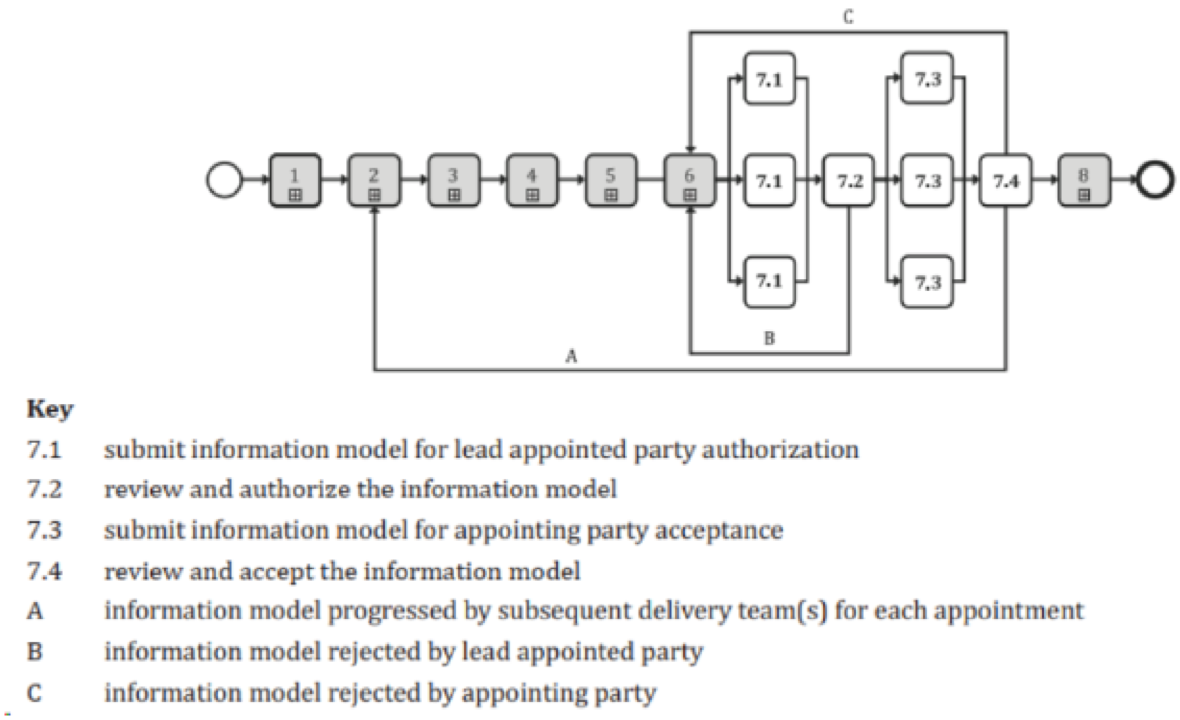


Figure 3.12: Information model delivery

III.2.10 Project close-out

This phase is characterized by strategic organization and digitization, making sure that the wealth of the information generated during the project's life cycle is systematically compiled, and accessible, and units the stage for efficient asset management and future projects.

Project close-out, marked by the concepts of organization and digitization, indicates the culmination of a construction project with an emphasis on leaving a legacy of well-organized and easily accessible information. By strategically managing and digitizing project data, organizations not only facilitate a smooth handover but also lay the foundation for future asset management, operational efficiency, and the continual evolution of construction practices.

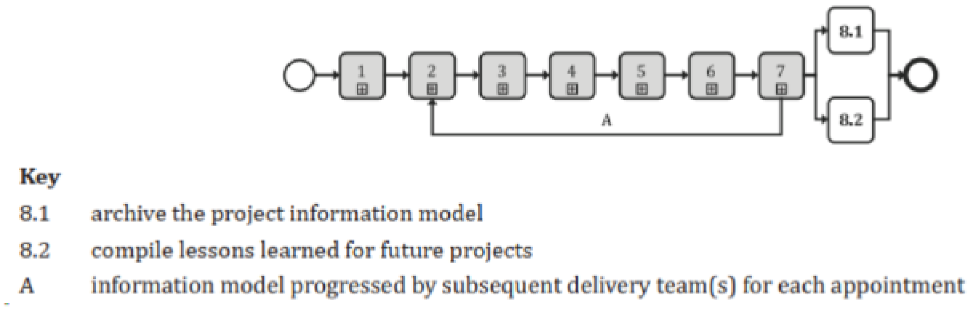


Figure 3.13: Project close-out

When we used VSM, the close-out reached some improvements due to the main goal of the both titles "strategic organization and digitization".

Standardized digital punch lists minimize errors and rework. Digital handover ensures all relevant information is readily available for facility management.

III.2.11 Standard idea

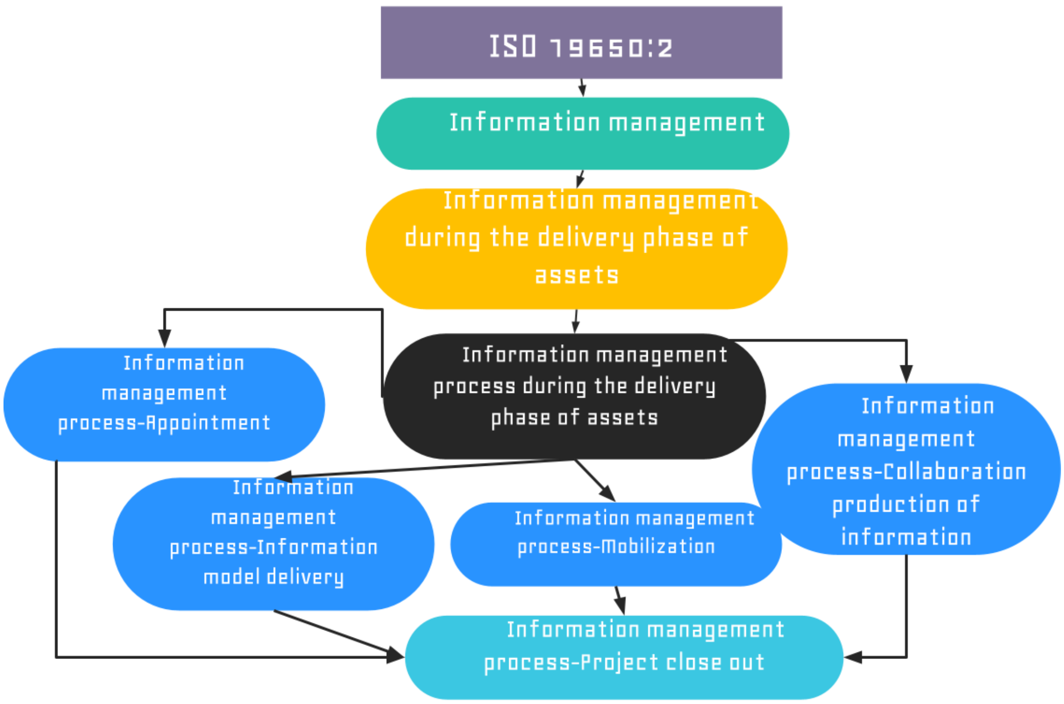


Figure 3.14: Standard idea

III.3 Reasons to adopt ISO 19650

Implementing ISO 19650 provides various advantages that improve the effectiveness, transparency, and safety of information handling in construction projects. The standard offers a well-organized system that enables teamwork, guarantees the reliable and precise delivery of information, and helps with successful management of assets throughout their entire lifespan.

Figure 3.15: Reasons to adopt ISO 19650

Below are several important factors to take into account when deciding to implement ISO 19650:

- The standard provides a data standardization framework with clear obligations for the delivery of information. Working with a standard process, groups can reduce time and value in producing coordinated information with using of shared information containers (Nicoleta Panagiotidou, BIM DesignHub. 2023)[125].
- Facilitating teams and the purchaser, this standard aids in identifying the client's Information Requirements. These requirements furnish consistent details regarding the project's objectives, guiding its efficient and effective delivery (Nicoleta Panagiotidou, BIM DesignHub. 2023)[125].
- In order to provide a clearer understanding of the tasks that have been undertaken in projects, this standard establishes information management functions. The information management function provides clarity of authority, responsibility, skills and competence for the team (Nicoleta Panagiotidou, BIM DesignHub. 2023)[125].
- Enabling collaborative working based on information containers, this standard facilitates the production and management of information. Utilizing common information containers reduces the time and cost of production, as well as streamlining the transmission of coordinated records (Nicoleta Panagiotidou, BIM DesignHub. 2023[125]).
- The essential idea of the standard is that the Project Information Model develops to grow to be the Asset Information Model. The Asset Information Model is a virtual construction

model and provides all the information necessary to help the powerful control of asset (Nicoleta Panagiotidou, BIM DesignHub. 2023)[125].

- A common data environment based on a variety of technologies that ensure the security and quality of information is introduced by this Standard. The information contained in the CDE is available to all project parties and allows a stable managed collaborative environment for task (project) delivery (Nicoleta Panagiotidou, BIM DesignHub. 2023)[125].

- Providing a framework to aid organizations in managing security risks during collaborative information sharing, this standard outlines measures aimed at reducing risks pertaining to the safety, protection, and resilience of assets, products, or services (Nicoleta Panagiotidou, BIM DesignHub. 2023)[125].

- Defining the federated information model as an amalgamation of individual discipline information models to produce a unified construction version or model, the standard ensures accessibility to all parties involved. This federated information model empowers the project team to make informed decisions and enhance resource allocation (Nicoleta Panagiotidou, BIM DesignHub. 2023)[125].

- The Level of Information Need framework is used to determine the minimal quantity of information needed to answer each requirement. The Level of Information Need describes the extend and detail of information and consists of the ideal dedication of quality, quantity and granularity of information (Nicoleta Panagiotidou, BIM DesignHub. 2023)[125].

- Across the entire life cycle of built assets and construction projects, irrespective of their scale or intricacy, this standard applies. It encompasses extensive estates, infrastructure networks, individual buildings, and various infrastructure components, as well as the projects or project units responsible for their delivery (Nicoleta Panagiotidou, BIM DesignHub. 2023)[125].

ISO 19650 offers a thorough structure for standardizing data and managing information in construction projects. It assists in recognizing client needs, improves teamwork, and aids in the development of a Project Information Model that transforms into an Asset Information Model. The standard also guarantees a safe and quality-managed shared data space, establishes the federated information model for improved decision-making, and details strategies for handling security threats. It provides advantages for a wide range of projects throughout the entirety of built assets' lifecycle (Panagiotidou, 2023)[182].

III.4 Chapter conclusion

To sum up, ISO 19650 Parts 1 and 2 offer crucial instructions for information management in construction projects, encouraging uniformity, openness, and cooperation. Part 1 establishes the fundamental principles and ideas, whereas Part 2 explains the process of managing information in the delivery phase. Implementing ISO 19650 comes with many benefits such as improved project efficiency, minimized risks, and streamlined information exchange. By establishing consistent procedures for managing information, it helps develop trustworthy Project and Asset Information Models, guaranteeing that precise and thorough data is accessible during the entire lifespan of a constructed asset. This standard improves information quality and security, as well as promotes improved decision-making and resource allocation, resulting in increased project success outcomes (Panagiotidou, 2023)[182].

The end goal is to have an Asset Information Model that the operations and maintenance parties can use it. This will ensure that up to 70% of the BIM benefits of the lifecycle of the project can be materialized, including cost and time savings (Succar, B. 2009)[8].

Chapter IV

Research Methodology

IV.1 Initial research ideas

IV.1.1 Methodological framework

The methodology used in this study involves a mix of qualitative and quantitative methods to offer a thorough analysis of the topic. This merging facilitated a detailed comprehension of the theoretical foundations and practical uses of ISO 19650. The utilization of Revit software made it easier to conduct in-depth practical simulations, allowing for the viewing and control of BIM models to assess different scenarios and workflows (Eastman et al., 2011)[5]. At the same time, Value Stream Mapping (VSM) used data to analyze operational workflows, showing any inefficiencies and suggesting ways to improve construction processes (Rother & Shook, 2003)[135]. The integration of these approaches allowed the study to offer theoretical insights and practical solutions for successful BIM implementation and information management in alignment with ISO 19650. This combination of methods provided a comprehensive understanding of the research issue and improved the accuracy and trustworthiness of the results, providing strong strategies for industry implementation(Creswell & Plano Clark, 2017)[183].

There are two potential methods that can be utilized in research based on the research's nature, objectives, or topic: the quantitative approach and the qualitative approach. (Basias & Pollalis, 2018)[188].
The quantitative approach studies a specific situation or phenomenon through statistics and the processing and analysis of data are done in numerical format. Normally, this type of approach is adopted when there is a need to analyze and process large volumes of data.

The numerical nature of the information in the quantitative approach ensures that it remains unaffected by personal and subjective opinions, which is a key benefit. Based on the type, goals, or subject of the study, researchers can choose either a quantitative or a qualitative approach. The qualitative approach involves examining experiences and behaviors of a particular phenomenon or situation without relying on statistical data or numerical analysis. It addresses the inquiries of What? In what way? At what time? and in what location? In conclusion, it can be viewed as a series of methods for interpretation, with the goal of explaining, resolving, and enhancing circumstances.

This approach allows for a more in-depth comprehension of the subject at hand, as well as a heightened recognition of its intricacies and characteristics. The variances in both approaches primarily stem from the goals, the method of data collection, the format of information gathered, and the level of investigation flexibility. The qualitative method provides more flexibility for researchers as it involves asking open-ended questions which enable in-depth exploration and elaboration of the research. Nevertheless, qualitative research necessitates greater care in implementation, particularly relying on the researchers' experience.

In order to enhance the research methodology, this study also incorporates the case study approach as described by Robert Yin. Yin (2018)[196] suggests that case studies are a valuable tool for examining current events in authentic settings, which complements the practical use of ISO 19650 in construction endeavors.

Yin stresses the significance of utilizing various sources of evidence in case studies, such as documentation and interviews.

Reviewing documentation, such as project reports and BIM implementation records, helps in gaining a historical and contextual comprehension of the data. Interviewing significant stakeholders who are part of BIM implementation provides detailed perspectives on their experiences, according to Yin (2018)[196].

Incorporating Yin's case study techniques improves the research by offering a thorough structure for gathering and examining qualitative data. This method supplements the utilization of Revit software for hands-on simulations and Value Stream Mapping (VSM) for operational evaluation. Using case study methods allows for a more thorough analysis of real-world situations and procedures in construction projects, providing more insight into the numerical results.

By utilizing the case study approach recommended by Yin (2018), the research gains an effective methodological structure that merges theory with real-world evidence.

IV.1.2 Visualization of ISO 19650 Implementation Process in Construction Management

The table and the figure below illustrate a structured approach to understanding the implementation of ISO 19650 in construction information management, emphasizing its sequential process. Beginning with an 'Introduction' to ISO 19650 and its importance in construction management, the diagram progresses through the exploration of 'ISO 19650 Part 1' and 'ISO 19650 Part 2,'.

These elements converge in 'Understanding BIM Implementation,' highlighting their collective contribution to grasping Building Information Modeling (BIM) concepts. Subsequently, the diagram branches into 'Revit Software Research,' emphasizing the function of BIM knowledge in informing software exploration, and 'Current State Value Stream Mapping (Structural Masonry),' which underscores the practical application of BIM comprehension, potentially addressing identified challenges. From there, the path leads to 'Future State Value Stream Mapping (Structural Masonry),' demonstrating how insights won from BIM understanding make contributions to envisioning and realizing an optimized future state. Ultimately, the journey concludes with an 'Impact of ISO 19650 on Construction Information Management' box, summarizing the broader implications of ISO 19650 adoption in construction information management practices.

Table 4.1: Integration of ISO 19650, Revit, and VSM in Construction Information Management

Components	Description	Key Points
ISO 19650	ISO 19650 is a global guideline for overseeing data throughout the entire lifespan of a constructed asset through Building Information Modeling (BIM). It focuses on a methodical way of managing information, promoting teamwork, and improving productivity in construction projects(Sacks, R., &, Liston, K. 2011)[5].	-Purpose and Scope: To comprehend the extent and utilization of ISO 19650 in construction projects. -Benefits: Increased coordination, minimized risks, and improved project results. -Stakeholders: Roles and duties involved in the implementation of ISO 19650 (ISO 19650-1)[2].
ISO 19650-1	ISO 19650's part 1 delves into the ideas and fundamental aspects of managing information within the framework of BIM. It explains the terms, definitions, and basic concepts necessary for successful information management (Anumba, C. J., & Evbuomwan, N. F. 2002)[140].	-Principles and concepts: Fundamental ideas like information needs, distribution, and sharing. -Information Management Process: Organized methods for handling data throughout the life of an asset (ISO 19650-1)[2].
ISO 19650-2	ISO 19650 Part 2 explains the specific procedure for project delivery, highlighting the important steps of information sharing and the duties of project members (Dawood, N., &,Iqbal, N. 2015)[141].	-Project Information Management: Process of sharing information, involving planning, implementation, and evaluation. -Roles and Responsibilities: Definite responsibilities of individuals in the project, guaranteeing responsibility and transparent communication as specified in (ISO 19650-2)[109].
BIM implementation	This component links the concepts of ISO 19650 to the tangible application of BIM. It examines the practical use of BIM concepts in real-life situations to enhance construction management according to (Azhar, S. 2011)[142].	-BIM Fundamentals: Summary of BIM procedures, equipment, and advancements. -Implementation Strategies: Approaches for incorporating BIM into constructionprojects, such as instruction and utilizing technology (Eastman, C. et al. 2011)[5].
Revit software	This segment explores the Revit software, a top BIM tool, to grasp its features and how it aligns with the implementation of ISO 19650 standards (Autodesk Revit Documentation)[57].	-Software Features: In-depth investigation of Revit's features, such as modeling, documentation, and analysis tools. -Integration with BIM: How Revit assists with BIM processes and adherence to ISO 19650 standards (Krygiel, E., & Nies, B. 2008)[4].
Current VSM	Value Stream Mapping (VSM) helps in recording the existing condition of structural masonry procedures, recognizing inefficiencies and opportunities for enhancement (Liker, J. K. 2004)[143].	-Process Mapping: Visual depiction of the current process in structural masonry. -Identifying Bottlenecks: Examination of present obstacles and shortcomings (Rother, M., & Shook, J. 2003)[135].
Future VSM	Drawing on information from BIM and ISO 19650, this part envisions an enhanced future state for structural masonry, enhancing productivity and decreasing wastage (Liker, J. K. 2004)[143].	-Future Workflow: Suggested enhancements and updated processes to enhance efficiency. -Implementation Plan: Transitioning from the present state to the future state involves a series of steps (Rother, M., & Shook, J. 2003)[135].
Impact of ISO 19650 on Construction Information Management	This last part sums up the consequences of implementing ISO 19650, emphasizing its advantages and ability to revolutionize construction information management (ISO 19650-2)[109].	-Enhanced Collaboration: Enhanced communication and collaboration among all parties involved. -Efficiency Gains: Simplified procedures and minimized project uncertainties.-Case Studies: Instances of effective application of ISO 19650 (Azhar, S. 2011)[142]. .
Connection - ISO 19650 and Revit	Revit supports the implementation of ISO 19650 by offering a tool for developing and overseeing digital models of assets' physical and functional features. It assists in managing detailed information processes needed for ISO 19650 Part 2, ensuring adherence to information requirements and streamlining information exchange (Krygiel, E., & Nies, B. 2008)[4].	
Connection – ISO 19650, Revit and VSM	VSM supports ISO 19650's focus on organized information management through visualizing processes, aiding in pinpointing areas for enhancing efficiency with BIM. When incorporated with Revit design: -Current State Analysis: VSM has the ability to identify inefficiencies in construction processes by showcasing the current state and suggesting improvements through improved information management and BIM integration. -Future State Design: By combining knowledge from ISO 19650 and the functionalities of Revit, VSM can support in creating an improved future state through efficient processes, minimized waste, and increased value delivery (Rother, M., & Shook, J. 2003)[135].	
Integrated approach	ISO 19650 Parts 1 and 2 establish the overall structure and specific procedures for managing information, highlighting the importance of working together and being effective. Revit enforces these standards through a strong platform for generating, organizing, and sharing BIM data, guaranteeing adherence to ISO 19650. VSM enhances existing processes, creates better workflows, and utilizes structured information management and collaboration environment supported by ISO 19650 and enabled by Revit, as explained by (Azhar, S. 2011)[142], (Sacks, R., & Liston, K. 2011)[5], (Dawood, N., & Iqbal, N. 2015)[141].)	

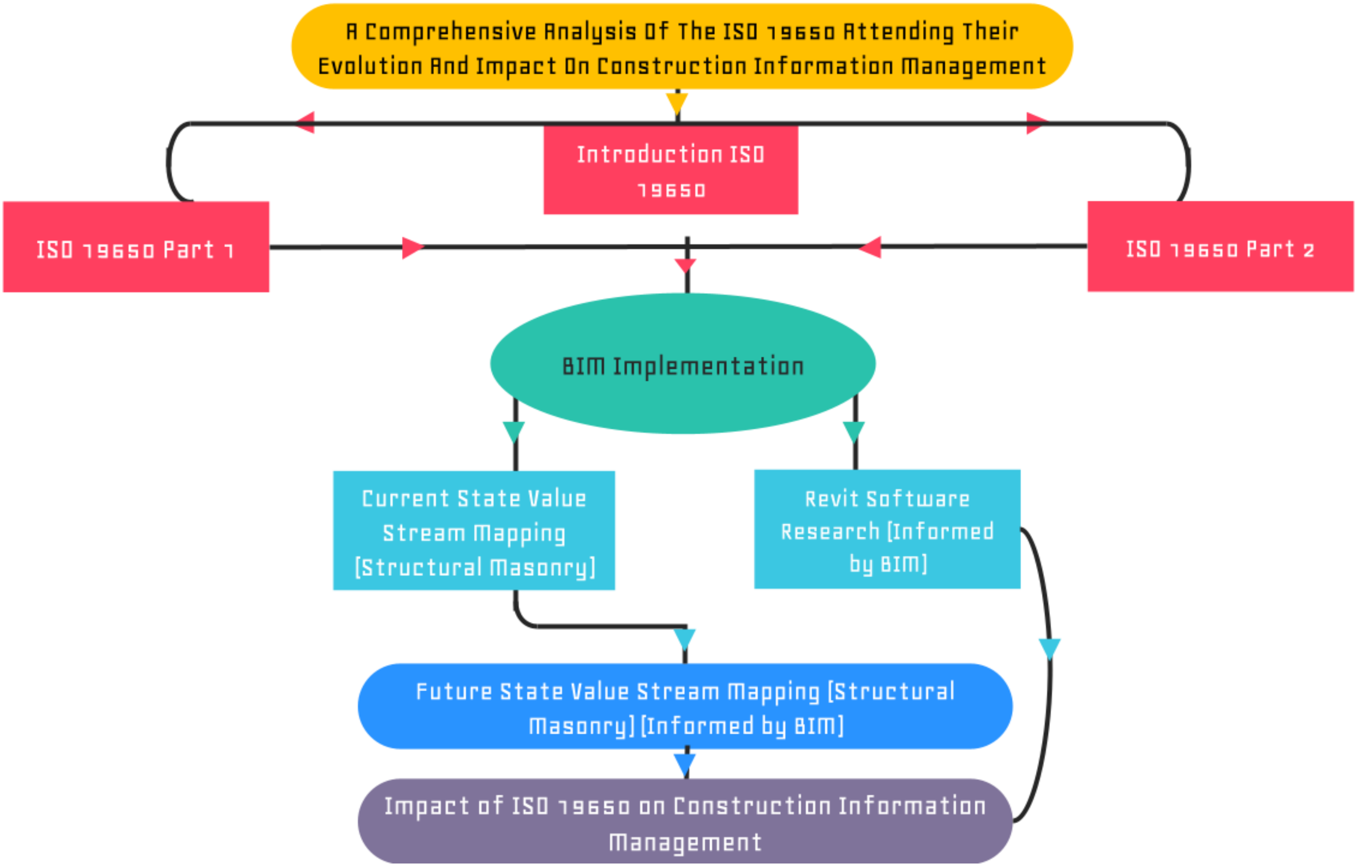


Figure 4.1: Sequential Process of ISO 19650 Implementation in Construction Information Management

IV.2 Revit software

IV.2.1 Opening

Autodesk Revit is a powerful building information modeling (BIM) software widely used in the architecture, engineering, and construction (AEC) industry. Here, he provides deep insight into the importance and value of Revit.

IV.2.2 Revit advantages

Revit, a robust Building Information Modeling (BIM) software, is extensively utilized in the construction sector for its capacity to improve productivity and teamwork. Some of its main benefits are enhanced design precision, live cooperation, and extensive documentation features. Revit enables smooth integration of different project disciplines, leading to improved coordination and fewer errors. Revit improves visualization and assists in accurate planning and execution by allowing the development of detailed 3D models. Furthermore, its strong data organization capabilities guarantee that every project data is current and readily available, in accordance with the demands of ISO 19650 standards for information management (Krygiel, E., & Nies, B. 2008)[4].

1. **Integrated Design and Documentation:**
   Description: Revit provides a unified platform for architects, structural engineers, and MEP (Mechanical, Electrical, and Plumbing) professionals to collaboratively design, document, and model a building or infrastructure project.
   Value: The integration of design and documentation within a single software environment enhances coordination, reduces errors, and improves overall project efficiency (Liston, K. 2011)[5].

2. **Parametric Modeling:**
   Description: Revit is known for its parametric modeling capabilities, allowing users to create intelligent 3D models with relationships between different elements. Changes to one element dynamically affect related components.
   Value: Parametric modeling facilitates design exploration, iteration, and quick adjustments, contributing to a more flexible and adaptable design process (Krygiel, E., & Nies, B. 2008)[4].

3. **BIM Collaboration:**
   Description: Revit supports multi-disciplinary collaboration through cloud-based solutions like BIM 360. This enables real-time collaboration, model coordination, and data sharing among project stakeholders.
   Value: Improved collaboration reduces communication errors, enhances project coordination, and streamlines the exchange of information among different teams (Azhar, S. 2011)[142].

4. **Comprehensive Project Lifecycle Support:**
   Description: Revit covers the entire project lifecycle, from conceptual design and detailed documentation to construction and facility management. It provides a holistic view of the project, supporting decision-making at every stage.

Value: Having a single platform that spans the project lifecycle contributes to better-informed decision-making and more efficient project management (Autodesk Revit Documentation)[57].

5. **Automated Documentation:**
   Description: Revit automates the generation of construction documentation, including plans, sections, and schedules. Changes made to the model are reflected in the documentation, reducing the risk of inconsistencies.
   Value: Automated documentation saves time, minimizes errors, and ensures that project documents remain synchronized with the evolving design (Autodesk Revit Documentation)[57].

6. **Family and Content Libraries:**
   Description: Revit includes a robust library of parametric families and components. Users can create custom families or leverage existing content, accelerating the modeling process.
   Value: Access to a rich content library enhances efficiency, standardization, and consistency in modeling, especially for commonly used building elements (Autodesk Revit Documentation)[57].

7. **Interoperability:**
   Description: Revit supports interoperability with other Autodesk products and industry-standard file formats. It allows for seamless collaboration with software such as AutoCAD, Navisworks, and third-party applications.
   Value: Interoperability ensures that Revit can be integrated into existing workflows and facilitates collaboration with stakeholders using different software tools (Autodesk Revit Documentation)[57].

8. **Visualization and Analysis:**
   Description: Revit provides tools for 3D visualization and analysis, including rendering, energy analysis, and daylighting simulations. This enables designers to assess the visual and performance aspects of the design.
   Value: Visualization and analysis tools support design decision-making by providing insights into the aesthetic and functional aspects of the project (Eastman, C. et al. 2011)[5].

9. **Global Adoption and Industry Standard:**
   Description: Revit has become an industry standard for BIM, with widespread adoption globally. Many AEC firms and professionals use Revit as their primary BIM tool.
   Value: Being an industry standard enhances collaboration, facilitates project transitions, and ensures compatibility with project partners using Revit (Autodesk Revit Documentation)[57].

10. **Continuous Improvement and Updates:**
    Description: Autodesk consistently updates and improves Revit, introducing new features, enhancements, and performance improvements in response to user feedback and evolving industry needs.
    Value: Continuous updates ensure that Revit remains at the forefront of technological advancements, providing users with the latest tools and capabilities (Autodesk Revit Documentation)[57].

IV.2.3 Developing a Dashboard for Revit Model Health

Combining the Forces of the Model Checker and Power BI

IV.2.3.1 Overview

This study is written to help educate Revit users on best practices and strategies for using the popular practice of data dashboards to monitor the overall "health" of the Revit model.(Revit model health dashboard sample) This is done by collecting measurable markers that impact the performance of the Revit model, and by visualizing the data for easy understanding and consumption. Where possible, the strategies presented laid out are leverage low cost solutions to make them accessible to all Revit users (Autodesk University 2017) [154].

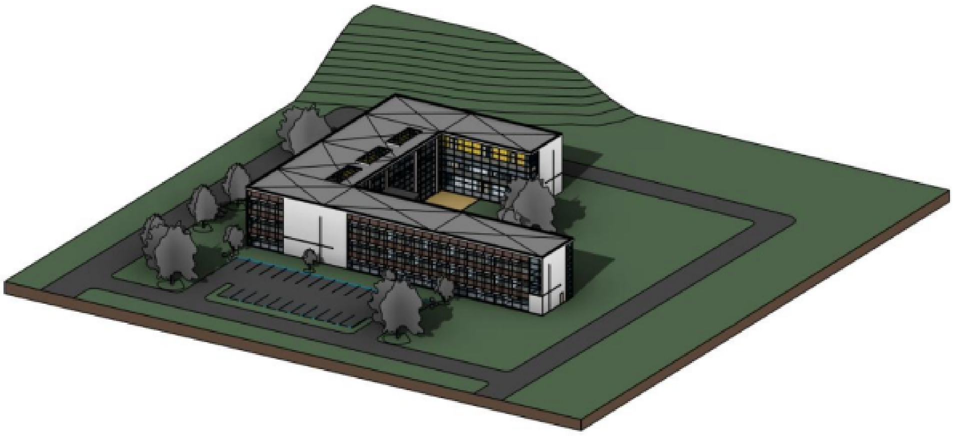


Figure 4.2: An example of a Dashboard

IV.2.3.2 Generalities

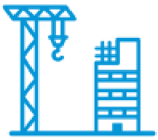
A Revit model is typically a single source for architects, engineers, and contractors to see their designs evolve and generate construction documents. At its heart, Revit project flies rely on an extensive database to collect and organize a whole host of different kinds of Information.

While the software should never dictate actual design, there are certainly better techniques to use the tools and functions in Revit for a design that will help create a more robust Revit project file and avoid production performance issues through design and construction. Many BIM, VDC, and Model Managers have their own metrics to monitor the health of a Revit model, but this is often done in time-consuming, manual ways. In addition, the review of this data can be difficult if the reviewer is not Intimately familiar with the Information collected, and how it is collected.

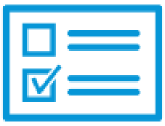
Over the past few years, across many industries, the use of "data dashboards" has become increasingly popular as It becomes easier to collect and organize large amounts of data and new tools are available that let users display and share the data in easy-to-understand graphics. Similarly, early, many design and construction firms have found use in visualizing the project and Revit model-related data to make it easier to track trends, fix Issues, and educate teams to be more effective (Bynum, P., Issa, R. R., & Olbina, S. 2013)[155].

IV.2.3.3 Types of data that can be tracked

Before creating a dashboard, It is important to understand what kind of data is often collected and reviewed. Then the team can determine what data is important to them



Design information and requirements
Design-related Information can be collected and reviewed, such as design area vs program area, code requirements around equipment counts, etc. This information is useful for PMs (Project Managers) to make sure the design is progressing along as expected and is meet the project scope.



Project data
Overall project Information such as timeline and schedule, budget Information and staffing numbers can be organized and displayed in a dashboard and is often used by PMs and PICs (Principals In Charge).

Model integrity
Related specifically to a Revit model, this info formation includes what kind of elements are being used and how they are being used as these can impact the performance of the model. This kind of information is critical to BIM Managers and Model Managers, and will be the focus of this white paper.

(Giel, B., Issa, R. R. A., & Olbina, S. 2010)[156].

IV.2.3.4 The reason to track model integrity

A properly maintained Revit model can perform extremely effectively through a project's lifetime, regardless of staff changes, building square footage, or design changes. Inversely, a small project that is being produced with a seemingly simple Revit file can see a host of issues If Revit best practices are not followed.

There are many quantifiable Items In a Revit model that BIM managers and Revit experts have identified over the years that may impact model performance. These Items are excellent metrics to watch throughout a project's design and construction, to target and resolve to keep the model running as smoothly as possible.

Internal training is another reason to monitor model integrity. A constantly recurring the model issue would be strong evidence for focused staff training and Improving skillsets (Autodesk University 2017)[154].

IV.2.3.5 Identifying data to track

With the focus on model integrity for a dashboard, what data to monitor needs to be Identified. This list will vary from organization to organization, but to narrow It down there are some key criteria to help identify what data is good to use and also what is easy to track in a dashboard.

Trackable | does the data correspond to information that is being collected in a Revit model?

Can be controlled with standards and best practices | can team members impact the performance of the model by editing the monitored elements?

Impact model performance | do the items, when not managed properly, typically causes problems In the Revit model?

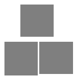
Examples

Some typical examples of Revit model Integrity related data that is often used for dashboard tracking include:

File size

Number of views

Number of warnings



Model and detail groups used

Number of elements

Number of in-place families

Linked files

geable elements

(Autodesk University 2017)[154]

IV.2.3.6 Data collection

Effective data gathering is essential in order to fully utilize Revit's benefits in managing construction information. Project teams can guarantee accuracy and dependability of data by incorporating automated processes, setting regular data updates, ensuring consistency, and expanding data collection beyond basic requirements. Improving BIM data quality enhances informed decision-making and project outcomes (Eastman, C., Teicholz, P., 2011)[5] (Autodesk University 2017)[154].

Table 4.2: Recommendations for data collection

Component	Content
Go automatic	First and foremost, the manual method of collecting model integrity data is problematic at best. Information is missed, It is very time consuming, and often gets skipped. Any serious efforts need to focus on automating the data collection as much as possible (Jernigan, F. E. 2007)[144].
Schedule it	Like any other project task, data collection happens most successfully when it becomes routine. It should be an identified scheduled task, possibly tied to another project task that is on a similar schedule: - Project review meetings - Model manager maintenance time - File delivery to consultants If the data collection is part of a series of other tasks, it will be performed more reliably (Azhar, S. 2011)[142].
Be consistent	It's important to not alter what data is being collected or the process of collection through a project. Data visualization requires reliable and consistent markers for tracking data over time. Any change to the data scheme will cause a break in the ability to monitor and track the information. If data tracking across projects is desired, it is also important to make sure there 1s an identifier to connect the data between collections. Often this can be difficult as there will be the need to change what is being specifically tracked or how it is being collected as new techniques are learned. Therefore, cross project data monitoring over time is often lost. Historical data can still be manually reviewed as necessary (Hardin, B. 2009)[145].
Go beyond the baseline data	It is simple to collect metrics that relate to specific Information in a Revit model. A visualization can be leveraged to look at information in new informative ways. For example, It is fairly simple to collect the number of warnings in a model and the file size. A dashboard report could easily be created that reports warnings saving report space and adding context to metrics that relate to each other (Smith, D. K., & Tardif, M. 2009)[146].

IV.2.4 Closing

The importance of Revit lies in its ability to streamline the design and construction process, improve collaboration, and provide comprehensive BIM solutions. Its value is evident in its robust parametric modeling, automated documentation, and support for multidisciplinary collaboration. As a widely adopted industry standard, Revit continues to play a key role in shaping the future of BIM in the AEC industry (Giel, B., Issa, R. R. A., &; Olbina, S. 2010)[156].

IV.3 Value Stream Mapping (VSM) operationalization

IV.3.1 Definition

Also known as Value Stream Analysis and Lean Process Mapping.

Value stream mapping (VSM) is a lean tool that uses flowcharts to document each step of a process. Many Lean practitioners consider VSM to be a fundamental tool for identifying waste, reducing process cycle times, and implementing process improvements.

VSM is a workplace efficiency tool designed to combine material processing steps with information flows and other important related data. VSM is an essential Lean tool for companies looking to plan, implement, and improve their Lean initiatives. VSM helps users create solid implementation plans that make the most of available resources and use materials and time efficiently (Rother, M., & Shook, J. 2003)[135].

IV.3.2 Profitable applications of Lean Value Stream Mapping

The original VSM template was created by Toyota Motor Corporation and implemented through material and process flow diagrams. This VSM helped us get a broad overview of the company's activities, showing the process steps required from order receipt to delivery of the final product. This allowed Toyota to eliminate unnecessary activities that create waste while maintaining the manufacturing process.

The "value stream" portion of the VSM system focuses on how to add value to products and services by changing the form and function of the market to meet customer needs. This involves adding features and functionality to a product or service that benefit the customer without wasting any further time or materials on the part of the company (muda, meaning waste in Japanese). (also called terms) (Womack, J. P., & Jones, D. T. 2003)[147].

IV.3.3 Scoping out the Value Stream Map

When planning a lean process or value stream map, understanding the scope of the value stream you are exploring is a good start. This map is her one area within the organization. However, if multiple factories, customers, or suppliers are involved, an enhanced layer map is created.

Think of high-level maps as views of a 60,000-foot value stream, a 30,000-foot asset-level map, and a 10,000-foot process-level map. To avoid being optimized in one area and sub-optimized in another, it is a good idea to start with a graphical representation of the asset-level map before drawing process-level or advanced-level maps. Recommended (Martin, K., & Osterling, M. 2013)[148].

IV.3.4 VSM steps

Value Stream Mapping (VSM) is an essential tool in lean management that helps to visualize and analyze how materials and information move through a process. VSM assists in pinpointing inefficiencies and opportunities for enhancement, ultimately resulting in increased productivity and decreased waste through methodical step-by-step mapping. The provided guidelines detail a systematic method for developing and executing a value stream map, guaranteeing a comprehensive and successful process (Martin, K., & Osterling, M. 2013)[148].

Step 1: Form a Team to Create the Lean Value Stream Map

Create a cross-functional team of senior managers and supervisors from across the organization. Personnel from various departments, including sales, customer service, warehouse, and operations, can freely exchange information and help ensure nothing is left out. Also consider including key suppliers in this group, as an outside perspective can be helpful.

The ideal team size is around 10 members. Small teams can miss important things, while large teams can be difficult to manage and coordinate (Li, Y. and Solís, J.L. 2018)[149].

Step 2: Creating the Current State Map – VSM Planning

To create a map of the current state, we collect data and information by "walking the flow" and interviewing the people performing the tasks. This is beneficial for two reasons:

- The team has the opportunity to review the entire process and look for waste.
- The people actually performing the work (operators, assemblers, technicians, etc.) can answer questions and eliminate misconceptions and preconceptions about how tasks are performed.

To keep your team in the loop, be sure to collect valuable information from your employees, such as:

- Cycle time or processing time
- Changeover time
- Reliability of equipment
- First pass yield
- Quantities
- Number of operators and shifts
- Hard copy information
- Electronic information
- Inventory levels
- Queue or waiting times

The information collected does not have to be perfect or overly detailed. As long as the data provides a relatively clear picture of the key issues, your team can start building a lean process map (Elizar et al 2017)[150].

Step 3: Start by Creating the Basic VSM Template

Once the team has gathered and reviewed the information gained from "walking the flow" it's time to begin creating your value stream map. Figure 4.3 below shows a common example and strategy for developing a VSM template.

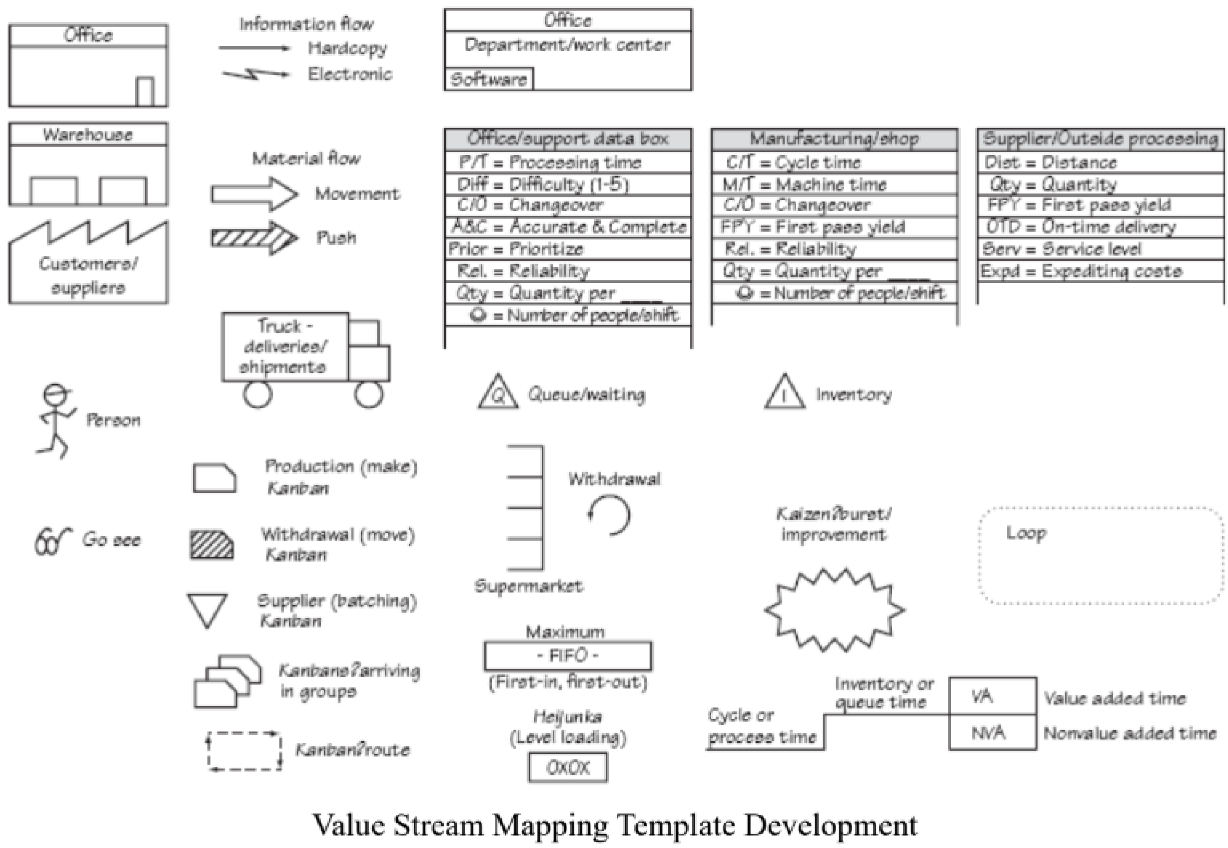
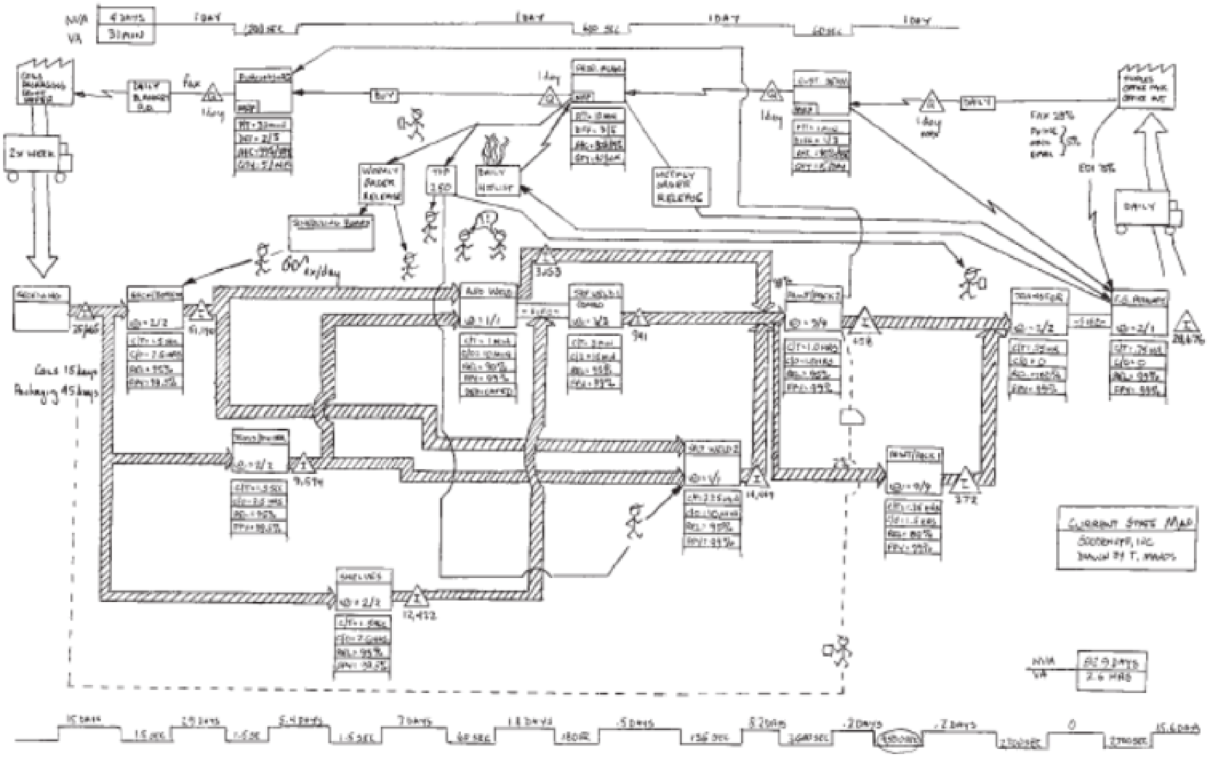


Figure 4.3: Value Stream Mapping Template Developement

Key areas on the map are:

- The upper-right corner for customer information.
- The upper-left corner for supplier information.
- The top half of the paper for information flow.
- The bottom half for material (or product) flow.
- The gutters on top and bottom to calculate value added and non-value added time.

Calculate cycle time and inventory time (in days) for material and information flow.
Each VSM is slightly different depending on the drawing process and type. Figure 4.4 below shows an example of his VSM map as it stands in use at a metal manufacturing company.



Value Stream Mapping Current State Map Example

Figure 4.4: Value Stream Mapping Current State Map Example

If this is one of your team's first VSM improvements, have the facilitator draw the cards on a large whiteboard, then have team members draw their own cards on paper (ideally in pencil). Current state maps are usually complete by the second day, but may still need refinement (Sudhakar, N. and Vishnuvardhan, K. 2017)[151].

Step 4: Creating the Future State Map

⇒ What is the takt time?

Tact is a German word meaning the baton by which the conductor controls the speed, beat, and timing of the orchestra. Cycle time refers to the frequency with which a part or component must be produced to meet customer demand. The formula is availability (per shift) divided by demand (per shift). for example:

- 22,000 seconds (time available)
- ÷ 200 pieces (demand)
- = 110 seconds/piece

⇒ Are there bottlenecks or constraints?

When gathering data while implementing Kanban, concentrate on cycle time or processing time. If any of these surpass the takt time, there is a danger of causing a bottleneck or constraint.

This may lead to high levels of work in progress (WIP) in certain areas or require extra processing time like overtime in order to fulfill demand.

⇒ **How can inventory (or queue time) be reduced?**

- Look at raw materials, work in process, buffer stock, safety stock, and finished goods stock to see if these can be reduced.

⇒ **Where can you improve flow?**

Is it possible to load material into cells or prevent material from stopping and waiting? If it is not possible to improve flow, can first-in-first-out lanes be established between processes?

⇒ **What other improvements are required?**

For instance, does the reliability of equipment need to be improved? Are the first-pass yield or quality levels acceptable? Is training in Kanban (workplace organization) needed? Does a new layout for an area need to be created?

In VSM, place improvement bursts (sticky notes or speech bubbles) around every item to indicate it needs improvement. Issues may include unreliable devices and low first-pass yields. Long switching times, large batches, waste from overproduction, movement, transportation, maintenance, defects, adjustments, etc. More or additional processing (Vilasini, N. and Gamage, J.R. 2010)[152].

Step 5: Creating the VSM Draft Plan

During a typical VSM event, a draft plan can be created based on information from the future state map. This plan requires further refinement, especially in determining the required resources such as time, personnel, and budget. A good plan includes a project description, the name of the project manager, potential team members, a timeline (or Gantt chart) of events and deliverables, cost estimates, impacts, goals, or benefits (Vilasini, N. and Gamage, J.R. 2010)[152].

IV.3.5 VSM application in the study

An exploratory case study was chosen as the research strategy, empirical research that analyses a phenomenon inside its current context, in which the researcher has little or no control over the events (Yin, 1994)[136]. It was necessary to discover the problems related to the unit of analysis: The execution of structural masonry on a floor, from the arrival of concrete blocks on site to the end of the last block row.

The structural masonry execution process was chosen because it is the most relevant activity in the budget and schedule of the project and, therefore, proposed improvements would generate a significant impact.
The cycle times collected are an average of the execution's productivity were additionally examined with Building Information Modeling (BIM) in order to pinpoint areas of congestion and enhance efficiency in the building process. This approach using BIM helped in fully grasping the details of how structural masonry was carried out, ultimately resulting in recommendations for improvement based on data analysis.

The collected data included the triangulation from three sources: administrative documents (productivity, people and material request spreadsheets), 30 minutes unstructured interviews (with two interns, a crane operator, a construction technician, a foreman and a site engineer) and direct observation (measurements of cycle times and wastes). The period of data collection on site was comprised between November 15th and 22th of 2023. The historical data of the worksheets were tracked before almost one month. The analysis focused on the identification of wastes and problems in the process, with a purpose to advocate improvements.

The delivery team's capability and capacity (III.1.7) and information delivery planning (III.1.9) are essential for achieving efficient organization, management, and waste reduction. Following key factors in task workflow is crucial for improvement and evolution, as evidenced in VSM results in chapter V.

Construct validity was addressed by comparing the data collected with principles reported in Lean Construction's literature and data triangulation through multiple sources of evidence. With regards to the outside validity, an analytic generalization is considered, in which the case observe generates theoretical propositions that might be relevant to different contexts.

Rother and Shook proposed five steps to implement Lean Thinking through VSM: Select a family of products, map the current state, analyze the current state, map the future state and elaborate the work and implementation plan (2003). In this study, I selected a stage of the productive process of construction instead of selecting a family of products to initiate VSM as suggested by Pasqualini and Zawislak (2005)[132]. The selected stage was the execution of structural masonry.

Figure 4.5: Structural masonry element

IV.4 Study methodology explanation and application

In this part, we investigate how Revit software, Value Stream Mapping (VSM), and the ISO 19650 standard are linked together. Despite their differences, these elements come together in the field of Building Information Modeling (BIM) and construction project management.

In collaboration, these components are intertwined as follows: Revit software creates the BIM models essential for the project's information control. VSM reviews and enhances the processes linked to developing and utilizing these BIM models. ISO 19650 sets the rules and procedures for handling the data in these models during the project's lifespan. This merger guarantees that BIM adoption is productive, successful, and in accordance with top-notch techniques in information handling and project execution.

IV.4.1 Revit Software and BIM

Revit software is leading in BIM technology, providing powerful tools for developing intelligent 3D models of structures and infrastructure. BIM involves using digital models of both physical and functional aspects of buildings to facilitate decision-making at every stage of construction. Revit plays a crucial part in aiding the development, visualization, and examination of BIM models (Krygiel, E., & Nies, B. 2008)[4].

In addition to 3D modeling, Revit also provides features for structural analysis, MEP design, Creates accurate material amounts through the generation of the BIM model (estimation of materials needed for building) and construction documentation. Collaboration among project stakeholders is improved by its ability to work with other BIM tools using the Industry Foundation Classes (IFC) standard (Eastman et al., 2011)[5]. Revit is essential for enhancing efficiency, minimizing errors, and guaranteeing the precision of construction procedures due to its capability to handle comprehensive project data and interact with various software tools (Azhar, 2011)[142]. Moreover, its ability to perform parametric modeling also enables. To enable real-time modifications to the model, guaranteeing that adjustments in one part of the design promptly appear in connected elements, thereby simplifying the process and promoting a cohesive project delivery strategy.

IV.4.2 Value Stream Mapping (VSM) and Organizational Efficiency

Value Stream Mapping is a method in lean management that examines and enhances the flow of materials and information needed to deliver a product or service to a customer. Emerging from the manufacturing sector, VSM has been implemented in numerous other industries, such as construction, to pinpoint and remove inefficiencies, improve operations, and boost overall effectiveness within organizations. VSM allows stakeholders to see the entire value stream, from idea to delivery, identifying bottlenecks, redundancies, and areas for enhancement. (Womack, J. P., Jones, D. T., & Roos, D. 2007) [164].

In this part, we examine the in-depth analysis of the workflow with data provided by company engineers. The data collected consists of different task parameters and workflow metrics, essential for grasping the current operational status and pinpointing areas for enhancement.

The information utilized in the Value Stream Mapping (VSM) came from interviews held between the technical team and the researcher, as provided by the company. These interviews made it easier to gather precise operational workflows, leading to precise analysis and improvement of construction procedures.

The information includes important parts of the process, like managing pallets with various block types, cycle times, lead times, stock durations, and crane activities. As an example, the company stated that they managed 118 pallets of different block types in one 8.8-hour workday, with each cycle taking 1.4 hours for 22 pallets. Moreover, unproductive time was calculated at 109.9 hours, with productive time at 52.8 hours, leading to a total lead time of 162.7 hours.

Additionally, observations of stock lengths on location show a range of one to ten days, which equates to 8.8 to 88 hours of labor. The crane data shows that it takes around 8 minutes on average to move a pallet of blocks, with the blocks needed for the first row of masonry being stored on the pavement 1 to 2 days in advance, leading to wait times of 8.8 to 17.6 hours.

The intricate metrics provide important insights into the construction process's existing workflow inefficiencies and bottlenecks. By utilizing this data, our goal is to carry out a comprehensive examination and follow-up Future State Mapping in order to simplify operations, maximize resource usage, and improve overall effectiveness (Womack, J. P., Jones, D. T., & Roos, D. 2007) [164].

IV.4.3 ISO 19650 Standard and BIM Management

The ISO 19650 standards offer a structure for handling data throughout the entire lifespan of a constructed asset with BIM technology. It details the steps, protocols, and criteria necessary for efficiently handling information during the design, construction, and operation stages. ISO 19650 highlights the significance of standardized procedures, effective communication, and cooperative working methods, closely matching the fundamentals of BIM (West, R., Mallett, R., & Harding, J. 2018)[165].

ISO 19650 boosts interoperability among project stakeholders and improves project data transparency and reliability by setting up standardized language and communication protocols (BuildingSMART International, n.d.)[124]. Furthermore, following the ISO 19650 standards helps in smoothly incorporating BIM data into asset management systems, allowing for well-informed decision-making during the asset's lifespan and enhancing the efficiency and eco-friendliness of constructed spaces (Kiviniemi et al., 2018)[184]. In essence, ISO 19650 is crucial in promoting efficiency, teamwork, and creativity within the construction sector, resulting in better project results and increased value for stakeholders.

IV.4.4 Connection Between Revit, VSM, and ISO 19650

The merging of Revit software, Value Stream Mapping, and the ISO 19650 standard signifies a combination of tech advancements, process improvement, and industry norms in BIM and construction management.

Revit acts as the essential tool for developing BIM models, enabling teamwork and information sharing among individuals involved in a project. Value Stream Mapping provides a structured method for examining and enhancing workflows, leading to increased efficiency and productivity within organizations. The ISO 19650 standard outlines a structured framework for managing information in BIM, underlining the significance of standardized processes and clear communication.

Organizations can improve interoperability, efficiency, and quality in their BIM projects by integrating Revit modeling practices with Value Stream Mapping methodologies and following the ISO 19650 standard (Hardy, P., & Bacon, C. 2016)[166].

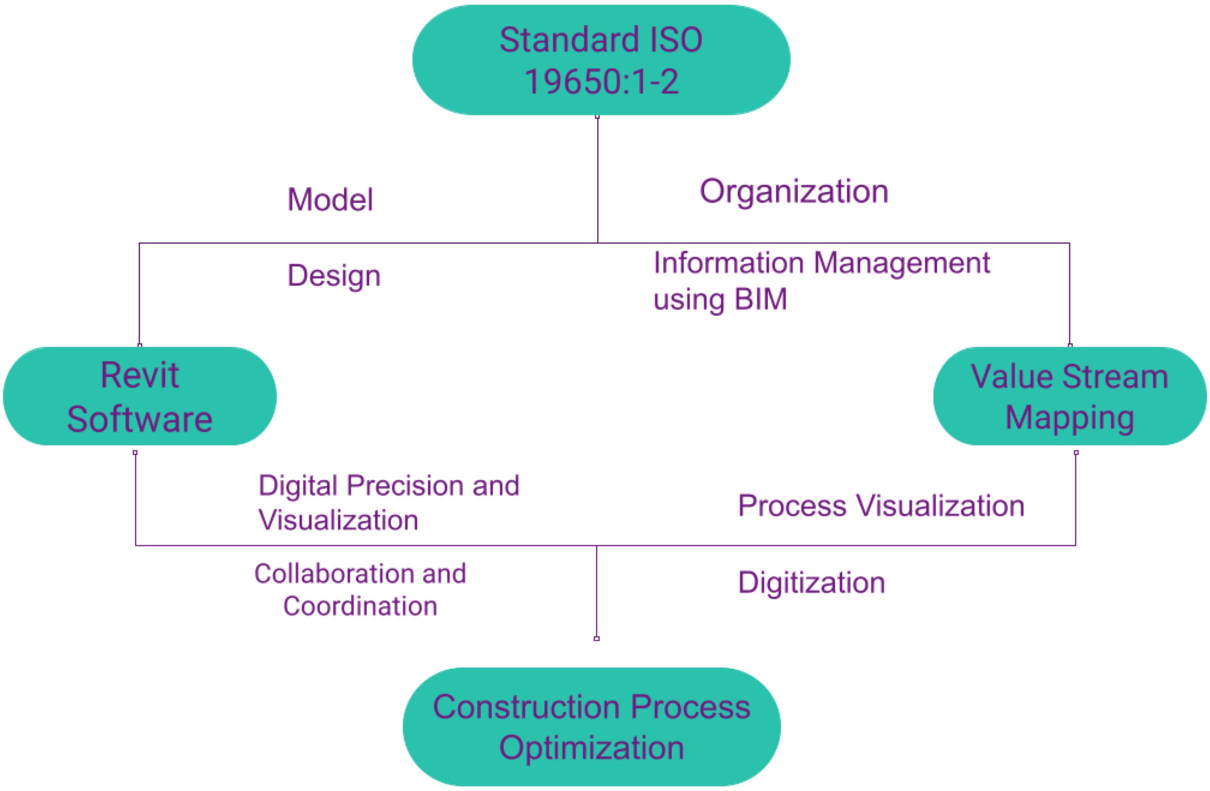


Figure 4.6: Connection Between Revit, VSM, and ISO 19650

Here below are some descriptions for the link points of our Figure 4.6:

- **Overview:** ISO 19650 is a global guideline for handling data throughout the entire lifespan of a constructed asset employing BIM. Sections 1 and 2 offer advice on ideas and rules, and the distribution stage of assets, accordingly (British Standards Institution. 2018)[192].

- **Role in Integration:** This standard acts as the basic structure that guarantees standardized methods in BIM, encompassing uniform information management and process optimization (British Standards Institution. 2018)[192].

- **Digital Precision and Visualization:** Revit provides resources for accurate digital depiction and visualization of architectural plans, creating detailed models that improve comprehension and communication between involved parties.

- **Collaboration and Coordination:** The software enables collaborative workflows by allowing several stakeholders to work simultaneously on the same model. This ability is essential for cooperation among various fields, decreasing mistakes and enhancing effectiveness.

- **Process Visualization:** VSM is a method of lean management used to analyze and plan how materials and information flow to deliver a product to a customer. VSM aids in visualizing processes, spotting inefficiencies, and improving workflows within the realm of BIM (Rother, M., & Shook, J. 2003)[135].

- **Digitization:** By combining VSM with digital platforms such as Revit, it is possible to digitize construction workflows, improving data precision and enabling immediate updates and oversight.
- **Outcome of Integration:** The goal of combining Revit, VSM, and ISO 19650 is to improve construction procedures. This includes enhancing accuracy in design and construction, improving visualization and communication, and ensuring efficient information management throughout the project's lifespan (Rother, M., & Shook, J. 2003)[135].

The combination of Revit, VSM, and ISO 19650 offers a thorough method for enhancing construction procedures. Revit's accuracy in digital work and collaboration features, along with VSM's process visualization efficiency and ISO 19650's information management standardization, improve the quality and efficiency of BIM projects when used together (Rother, M., & Shook, J. 2003)[135].

Chapter V

Results

V.1 Project presentation

V.1.1 Entrance

This chapter will first provide an overview of the project, with the aim of better explaining the functionality of the building. Subsequently, an architectural presentation will be developed to highlight the distribution of the various adopted spaces. Finally, the structural design of this project will be presented.

Through the use of thorough research techniques like case studies, a deep understanding of the project's surroundings was achieved. This part will explore how research findings can be applied practically to guide the design process, ensuring the final structure successfully aligns with the needs and preferences of its users.

This presentation will not just display the building's visual and spatial layout but will also explore how structural principles and design factors are applied in practice. The presentation will show how design solutions meet functional needs and create a pleasing environment by combining architectural research, spatial analysis, and 3D modeling.

V.1.2 Site layout and description

The Carthage Residence project is located in "Jardin de Carthage, Elissa Avenue". It covers an area of approximately 2500 m2 and includes 2 blocks of 6 floors and a basement with a double-height ground floor, which houses 6 commercial premises, 66 residential units, and an underground parking. In the central part, there will also be a green square and a pedestrian path.

Figure 5.1: Site location

V.1.3 Project briefing

Our project involves the design and study of the superstructure. The building covers an area of approximately 1322.8 m^2 in a total area of 1820m^2. The two blocks consist of 6 floors with a total height of 24.2 meters. These two blocks will be placed on a common basement.

Figure 5.2: Virtual project modeling

V.1.4 Architectural description

This architectural description offers a summary of the building's structure and design, including the basement, ground floor, first floor, and additional levels, emphasizing important features and purposes of each level.

- Basement:
  - A ramp with a gradient of 16%, consisting of two lanes (one for descent and one for ascent).
  - 72 parking spaces, each approximately 5m x 2.2m, including 3 spaces designated for people with disabilities.
  - Stairs with staircase landing.
  - Maintenance room.
  - 2 elevators (double access) with 1 vestibule.
  - 16 storage rooms
- Ground floor and 1st floor
  Includes spaces for various uses: double-height commercial space with 6.3m floor-to-ceiling height in block B and residential spaces with floor-to-ceiling heights of 2.88m and 2.95m in block A.
- The other floors
  These floors have nearly identical architecture. Each floor includes:
  - Living room/kitchen, bedrooms, bathrooms, shower rooms, etc.
  - 2 staircases.
  - 2 elevators.

Figure 5.3: Main facade

Figure 5.4: Patio 1 facade

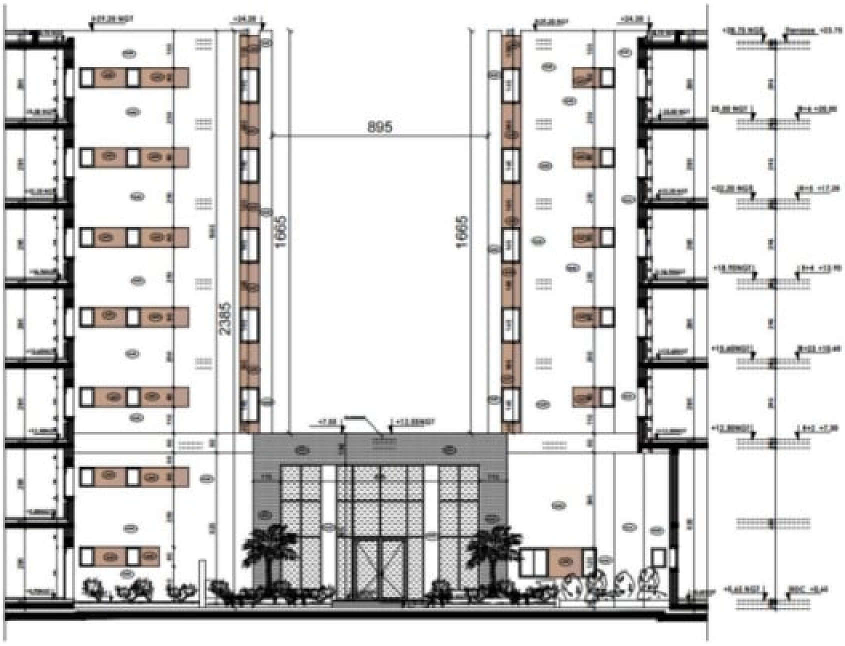


Figure 5.5: Patio 2 facade

Figure 5.6: Patio 3 facade

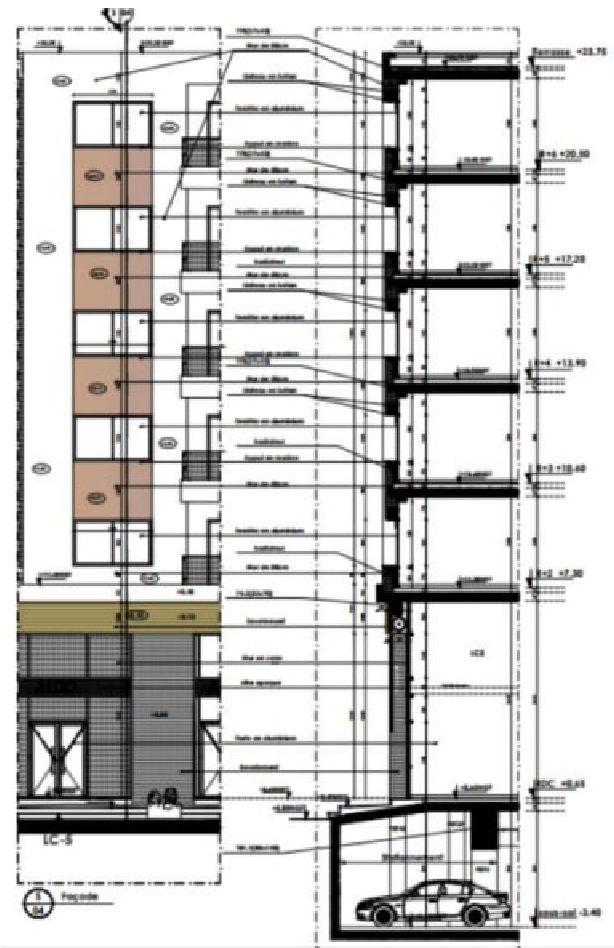


Figure 5.7: Section 1

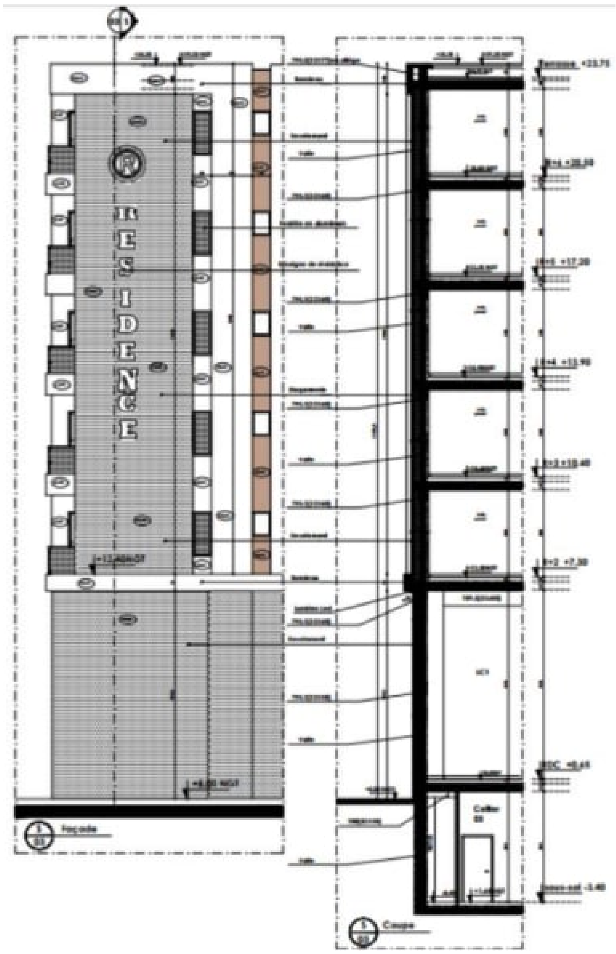


Figure 5.8: Section 2

V.2 Revit modelization (Work Process)

V.2.1 Load template (structure template)

Beginning the process of creating a Building Information Model (BIM) for structural engineering in Revit starts with loading a structural template. A pre-configured file in Revit that includes predefined settings, standards, and components necessary for a specific project type is known as a template. The structural template is designed specifically for projects that prioritize structural elements, guaranteeing that the essential tools and settings are easily accessible for precise and efficient modeling (Revit Documentation by Autodesk)[57].

1. « file »
2. « option »
3. « file location »
4. « add the template to use » The added template will subsequently be displayed in the "project" list.

By adhering to these procedures, you can guarantee that your structural framework is established on a strong base with the correct configurations and guidelines from the beginning. This method not only simplifies the modeling process but also improves the overall quality and consistency of your project results (P., Sacks, R., & Liston, K. 2018)[160].

V.2.2 Level creation

In Revit, levels are utilized to set the elevations for various building elements. They are essential for constructing floors, roofs, ceilings, and structural components. Properly establishing levels at the start of the project guarantees that all following modeling tasks are properly aligned and coordinated (Eastman, C., Teicholz, P., 2018) [159].

1. Select elevation
2. Choose one of the directions (EAST/SOUTH/WEST/NORTH)
3. Create all levels

By adhering to these instructions, you can guarantee that the vertical arrangement of your project is properly organized and uniform, establishing a strong base for additional modeling and coordination tasks in Revit (Revit Documentation by Autodesk)[57].

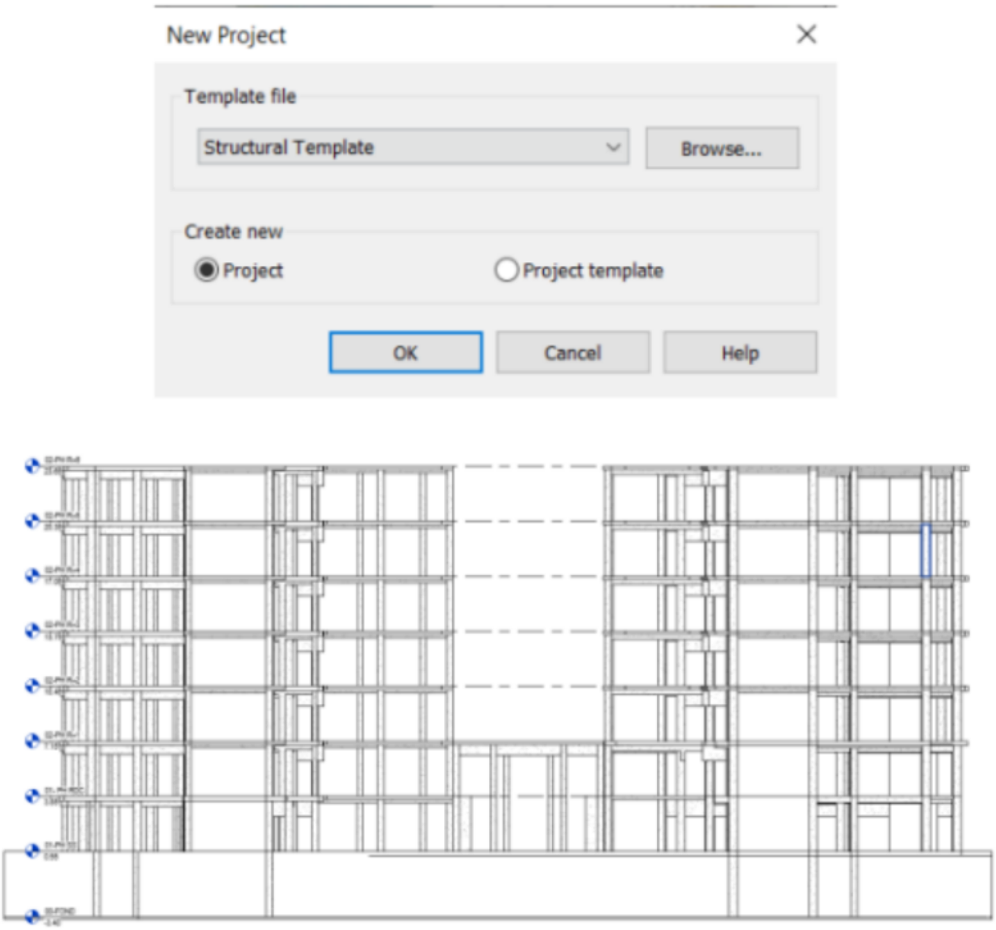


Figure 5.9: Creating levels for my project

V.2.3 Insert Autocad file

Including an AutoCAD file in Revit allows you to utilize 2D CAD drawings as references or underlays for your 3D model. This procedure is crucial for projects that have utilized AutoCAD for previous design work, enabling smooth integration and guaranteeing proper alignment of all design components (Krygiel, E., & Nies, B. 2008)[4].

1. Selection of a plan view (foundation, or floors, etc.)
2. Insert
3. Link CAD the correct file

Note: If the floors are different, each floor must be stored in a unique location with the same coordinates. For example, coordinate point (0,0,0) to reserve the overlay after importing the ground. If they are the same, work on a single layer and then copy the other layers with it. By adhering to these instructions, you can seamlessly incorporate AutoCAD files into your Revit project, utilizing current design data and guaranteeing precise and coordinated project documentation (Revit Documentation by Autodesk)[57].

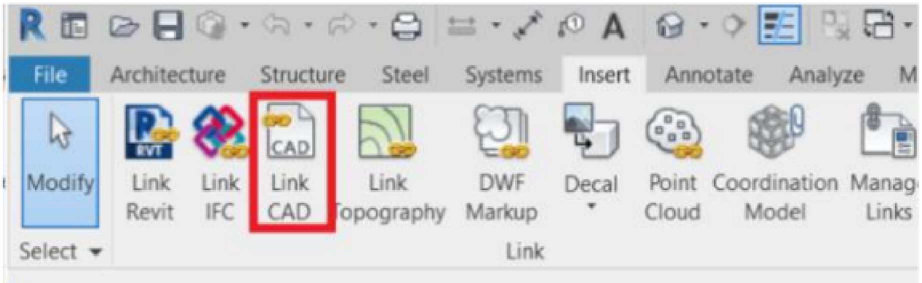


Figure 5.10: Insert AutoCad file

V.2.4 Place the structural elements

Structural elements are crucial in Revit for establishing a strong and secure building model. These components both establish the structural support system and guarantee the design complies with engineering principles and standards. The procedure includes utilizing Revit's structural features to precisely position and set up these components in the model (Krygiel, E., & Nies, B. 2008)[4].

1. Drawing structural elements (columns, beams, footings, walls, etc.)
2. Each element in its view with the main height and width for example: Drawing of beam width 60 and height 40.

To draw the elements of the structures, you must first:

1. Click on "Structure" in the taskbar at the top: the structure elements are displayed.
2. Choose the element (column, slab, beam...)
3. Modify the type of the element for example the beam chosen to draw is "Po (50x30)"
4. You need to adjust the height and width, as well as the material (metal or concrete). You must also duplicate and label this beam so that it is finally displayed in the formwork plan with the name

We will do the same for the other elements.

By adhering to these instructions, you can guarantee that the structural components in your Revit design are correctly positioned and set up, establishing a strong basis for additional modeling and coordination tasks (Revit Documentation by Autodesk)[57].

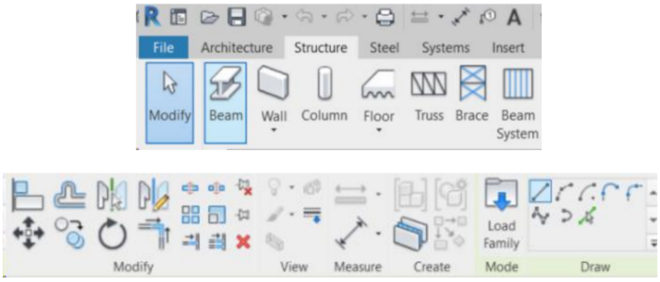


Figure 5.11: Place the structural elements

V.2.5 Annotate structural elements

Annotations in Revit enhance the structural model by providing clarity and detail, facilitating a better understanding and interpretation of the design by all stakeholders. Accurate annotation is crucial for developing construction documents, conducting quality inspections, and promoting collaboration between various fields (Sacks, R., & Liston, K. 2018)[160].

1. Click on “annotate” in the taskbar
2. Select ’label by category’ or ’label all.’ For labeling by category, annotate the category, and choose, for example, a single beam or column. For labeling all, annotate all categories, for instance, all footings.

By adhering to these guidelines, you can make sure that your structural components are properly labeled, creating detailed and easy-to-understand documentation that aids in both comprehension and construction (Revit Documentation by Autodesk)[57].

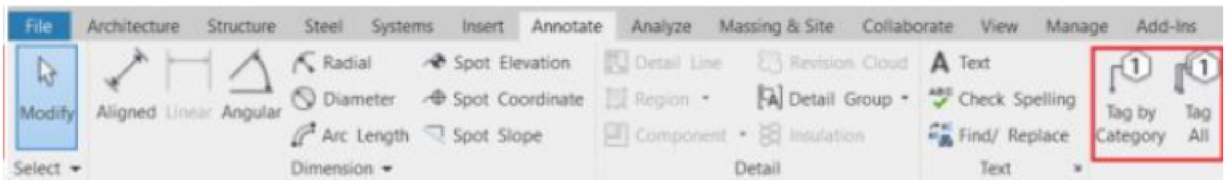


Figure 5.12: Annotate structural elements

V.2.6 Formwork Plan Development

Revit formwork plans consist of the design and specifications of the temporary structures utilized to mold and uphold concrete until it sets and attains adequate durability. These plans are crucial for directing construction teams, guaranteeing safety, and upholding the quality of the completed concrete structure (Krygiel, E., & Nies, B. 2008)[4].

Once all elements are in place, drawn, and labels are displayed, we proceed with dimensioning and drawing of openings and hatched areas. To dimension:

1. Click on “annotate”
2. Choose “linear”
3. Begin dimensioning the plans

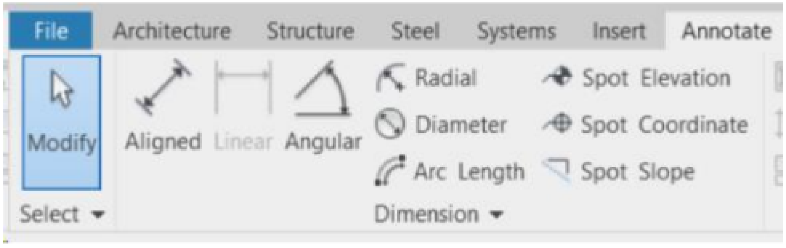


Figure 5.13: Formwork Plan Development

To hatch areas:

1. Click on "annotate"
2. Choose "region"
3. Trace the shapes and select the hatch patterns

By adhering to these procedures, you can guarantee that your formwork strategy is thorough, precise, and properly organized, offering crucial instructions for the building crew and aiding in the effective completion of the project (Revit Documentation by Autodesk)[57].

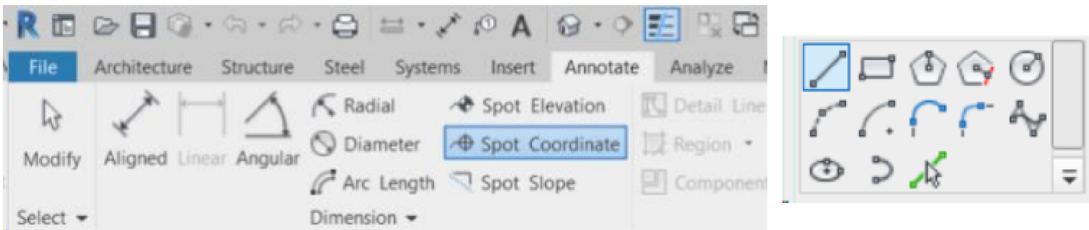


Figure 5.14: Hatch areas

V.2.7 The 3D Model

The 3D model constructed in Revit provides a detailed representation of the building's load-bearing components, guaranteeing structural strength and steadiness. The model consists of different parts such as columns, beams, foundations, and structural framing, carefully planned to uphold the architectural features of the building (Ambrose, J., & Tripeny, P. 2017)[161].

By making use of Revit's sophisticated modeling features, every structural component is carefully placed and measured to adhere to engineering specifications and building regulations. The model includes intricate connections and joints, enabling smooth integration and coordination with architectural and MEP systems ((BIMForum). 2018)[162].

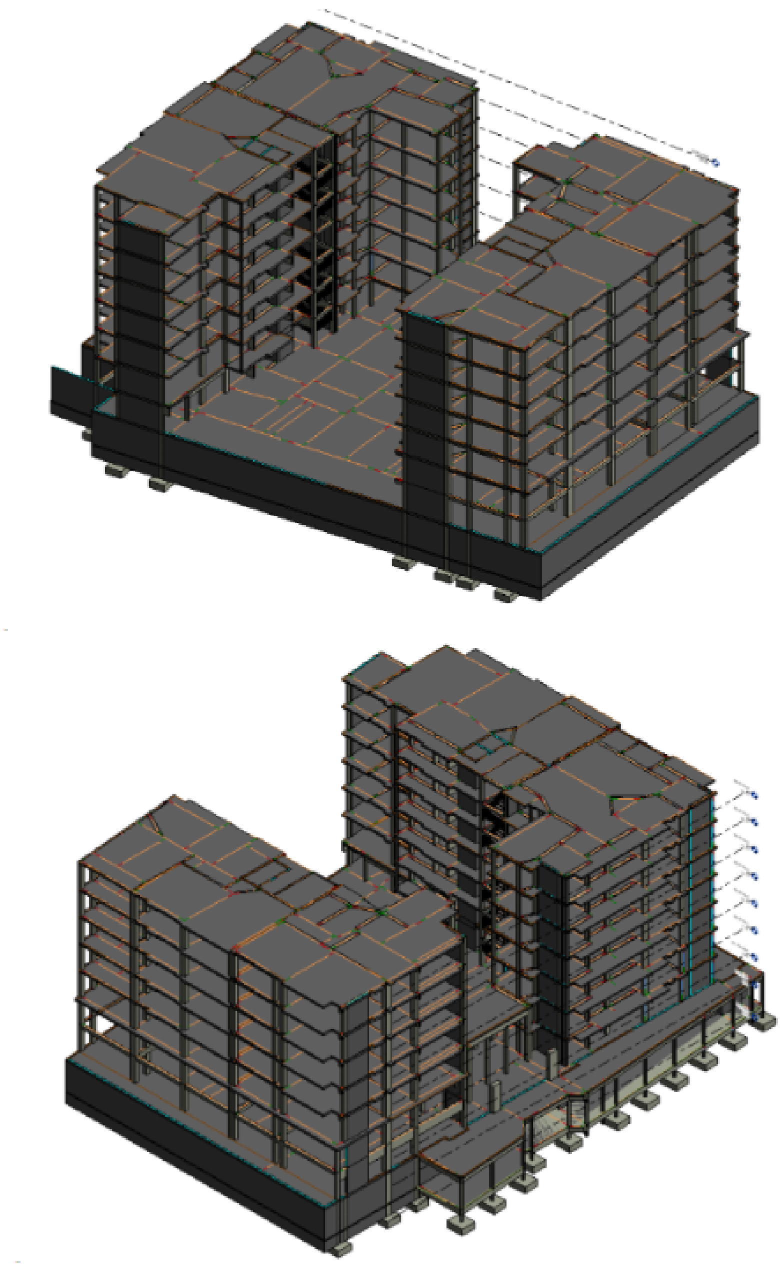


Figure 5.15: 3D Views

By developing a thorough structural model, essential elements of the building's design and construction can be clearly conveyed, enabling stakeholders to make informed choices and enhance the overall building performance (Nawari, N. O. 2017)[163].

V.2.8 Analytical model

The analytical model is a basic form of the physical model used to analyze and design structures. It simplifies the physical components into lines, nodes, and surfaces that are utilized by structural engineers for load calculations and simulations (Sacks, R., & Liston, K. 2018)[160].

Create a physical model for coordination and documentation, along with an associated analytical model for structural analysis.

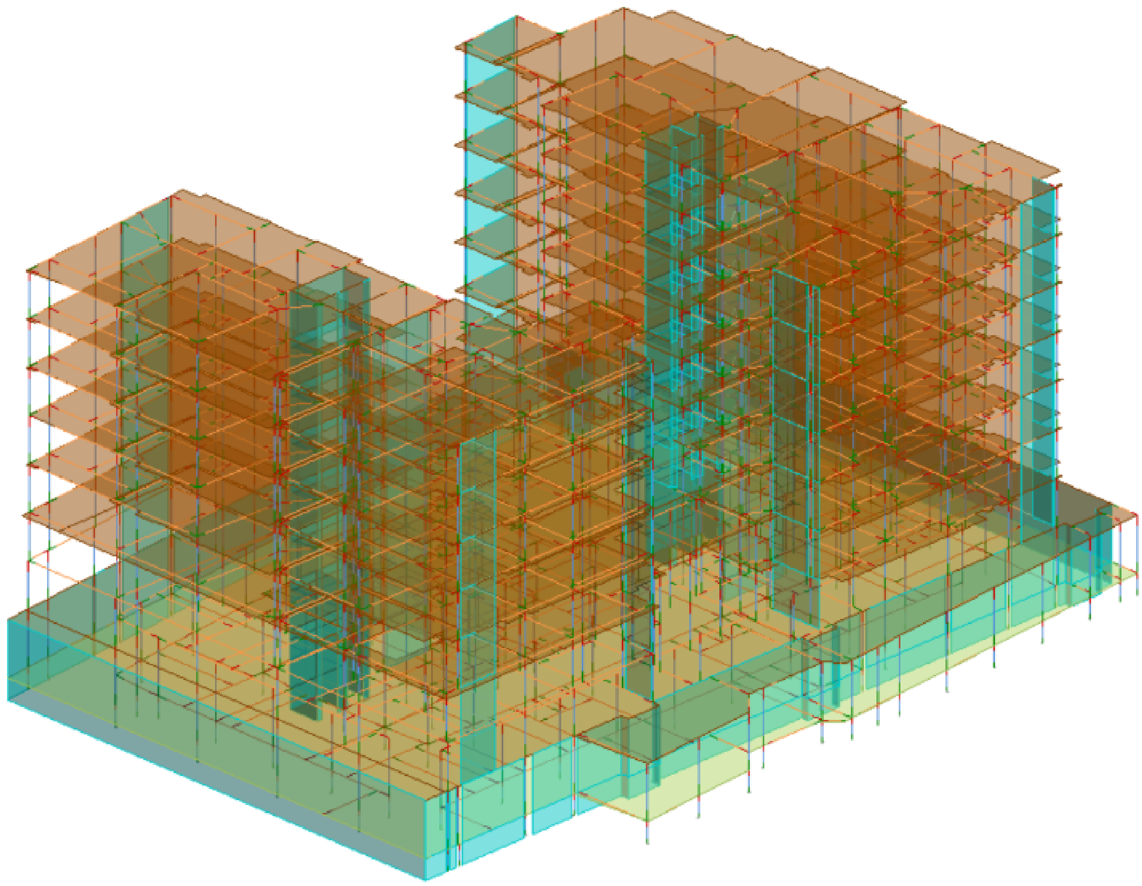


Figure 5.16: Analytic model

V.2.9 Completion

When discussing the topic of "VSM implementation," it is evident that Revit aids in visualizing and coordinating design elements, whereas Value Stream Mapping (VSM) enhances this by analyzing and enhancing workflow efficiency in construction project management (Rother & Shook, 1999)[179]. BIM and VSM are methods that work well together, providing different perspectives on the construction process. BIM concentrates on digitally displaying the physical and functional attributes of a facility, facilitating teamwork and alignment among different parties during the entire project phase (Becerik-Gerber & Ku, 2011)[185]. Alternatively, VSM is a streamlined management tool that evaluates and enhances the movement of materials and information within operations, pinpointing inefficiencies and areas for advancement (Rother & Shook, 1999)[179].

The connection between Revit modeling and VSM revolves around their shared goal of enhancing project outcomes and boosting project performance by using streamlined processes and collaborative approaches (Becerik-Gerber et al., 2009)[187]. Through the combination of BIM and VSM, construction project teams have the ability to recognize and remove inefficiencies, lessen waste, and simplify workflows, resulting in improved project results (Koskela et al., 2003)[186]. This alignment supports the ISO 19650 standard, which highlights the significance of efficient information handling and teamwork during the project's entire duration (ISO, 2018)[95].

In conclusion, utilizing both BIM and VSM proves to be a strong strategy for managing construction projects by incorporating digital tools and lean principles to improve processes and boost performance.

V.3 VSM implementation

V.3.1 Opening

Expanding on the knowledge acquired from Revit modeling, we shift our focus to applying Value Stream Mapping (VSM) methodologies in construction project management. VSM provides a methodical way to examine and improve workflow effectiveness, helping stakeholders pinpoint value-adding tasks, remove inefficiencies, and boost productivity as a whole. As we delve further into our investigation, we will analyze both the present and future mappings with the goal of finding areas for enhancement and promoting operational excellence. The link between Revit modeling and VSM implementation shows how design and construction are closely connected, emphasizing the need for collaboration and ongoing improvement to ensure project success, aligned with ISO 19650 principles (Hardy, P., & Bacon, C. 2016)[166].

The Architecture, Engineering, and Construction (AEC) industry has long struggled with issues surrounding its poor performance in production management, mainly due to the prevalence of waste resulting from a focus on conversion activities in managerial methods (Koskela, 1992)[126]. There is an increasing interest in the principles and tools of Lean Thinking (LT) among both academia and industry, seen as a solution to waste according to Womack and Jones (1996)[127].

Emphasizing that enhancing long-term improvements in the AEC sector requires a shift in the mentality of individuals involved, rather than just using individual tools to address particular issues (Koskela, 1992)[126] is crucial. In this situation, Value Stream Mapping (VSM) is a technique used to systematically apply Lean Thinking principles, leading to enhancements across the entire process flow (Picchi, 2003)[128].

Prior studies have explored the effectiveness of VSM in different AEC activities like design (e.g., Lima et al., 2010)[129], home building (e.g., Yu et al., 2009)[130], drywall and ceramic installation (e.g., Bulhões and Picchi, 2011)[131], ceramic brickwork (e.g., Pasqualini and Zawislak, 2005)[132], and concrete block construction (e.g., Al-Sudairi, 2007). Nevertheless, limited research focuses on enhancing procedures concerning the implementation of structural masonry through VSM, primarily focusing on VSM measurement parameters (e.g., Ortiz et al., 2012a[133]; Ortiz et al., 2012b[134]).

This study suggests enhancements in the construction of structural masonry by applying VSM to identify inefficiencies and create a vision for the future. The primary benefit is in minimizing inefficiencies in the process flow, creating an optimal scenario despite constraints on budget and schedule, sparking contemplation among academics and professionals exploring the effectiveness of Lean Construction in various projects.

The company offered detailed information on their existing masonry processes. This encompassed details regarding obtaining materials, managing, storing, and assembling on-site. In-depth measurements like cycle times, lead times, inventory levels, and labor utilization were also acquired. This data enabled an accurate depiction of the present situation, pinpointing crucial areas of inefficiencies and wastage in the current process.

After examining the present situation, consultations were held with the project managers, engineers, and site supervisors of the company to visualize an improved future state. The future design plan integrated Lean principles with the goal of minimizing identified inefficiencies, improving workflow effectiveness, and boosting productivity. The information gathered from these conversations helped outline the planned enhancements and played a crucial role in developing a practical and attainable vision for the future.

The VSM was based on practical, actionable insights thanks to the data-driven approach. The company not only gave the needed data, but also helped create a continuous feedback loop for improving future plans. This partnership highlights the significance of industry involvement in properly implementing Lean principles and is in line with ISO 19650's focus on continual enhancement and well-informed decision-making.

Utilizing VSM in conjunction with structural masonry (block bricks) closely follows the main principles of ISO 19650, which involve improving collaboration and communication, effectively managing information, minimizing waste, promoting data-driven decision-making, and enabling ongoing enhancement. Through the incorporation of VSM in the structural masonry procedure, the project follows ISO 19650 guidelines, guaranteeing streamlined, productive, and enhanced construction techniques (ISO 19650:1-2)[2][109].

Therefore, the overview of applying VSM with Structural Masonry concerning ISO 19650 focuses on key aspects such as Improving Collaboration and Communication, Managing Information, Minimizing Waste and Boosting Efficiency, aiding Decision-Making with Reliable Data, and promoting Ongoing Enhancement (Pasqualini, F., & Zawislak, P. A. 2005)[132].

V.3.2 Objective

Value Stream Mapping is a device that permits the visualization and knowledge the material and information flow as the goes through its value flow so we are talking about one of the most important goals of the Standard ISO 19650. In order to achieve the continuous or pulled flow, a proposition of an ideal production chain can be made, getting as close as possible to produce only what clients want and when they need it (Rother and Shook, 2003)[135]. The focus is on eliminating wastes and, therefore, increasing the amount of time that effectively adds value to the process as stated the ISO 19650 in the part of Organization and Digitization.

V.3.3 Current state mapping and analysis

The current state mapping was elaborated with the reason of applying the principle of the value chain identification, presenting a panoramic view of the stages, from the request of blocks to the ultimate masonry floor completion. Information about Cycle Time (CT), inventories, personnel involved, issues affecting production and quality problems was collected during all method stages. A working day containing 8.8 hours was adopted.

The process begins from the blocks request made by the project team, as proven in Figure 5.17. The construction technician exams the stock of blocks on site every Friday, compares it with the quantity wished for the next week according to the bricklayer's productivity and makes the order, adding a safety margin of material sufficient for a week of work (1.5 to 2 pavement inventory, depending on the block typology). The construction technician highlighted that the project team has already confronted issues associated with block's supplier reliability, such as: delay in block deliveries and dimensional variability not complied with standards. As a result, the construction company replaced the blocks' supplier three times. Therefore, the technical team fears to be broken again, mainly by the shortage of material delivery.

One hundred and eighteen pallets of various block typologies are required for the execution of a complete pavement masonry, of which 22, 62 and 34 are respectively for the execution of the first, second to fifth and sixth floor. Eight munck vehicles deliver these pallets with a capacity of sixteen pallets each, which deliver the work throughout the week. The number of trucks per day is variable it relies upon at the availability of the supplier.

After the arrival of trucks in the construction site, the unloading is finished with the supervision of the stockroom assistant who indicates the area in which the materials should be placed. It was observed that the blocks are unloaded where there is access to the trucks and area on site, i.e., there is no standardization or control of where the stock will be, it is a point completely does not match with the ISO 19650. In one hour, the supplier company's workers unload the sixteen pallets. 22 pallets are required for the primary floor of the masonry. For this reason, in the current state mapping the unload time for 22 pallets (1.4 hours) was considered as the initial process. Additional unloading happens simultaneously to the execution of the masonry.

After the block stock is located on site, the vertical transport stage is commenced with the assist of two cranes. At this level, both the production team and the researchers validated a production bottleneck. There was a delay in the blocks deliver due to the way information flows to the crane operator, through verbal conversation in real time. As a result, there was a decrease in productivity and even a total stoppage of some block laying team, achieving as much as a 6-hour wait.

The signalman (the eyes of the crane operator) chooses the pallet that is more accessible to perform after being knowledgeable of the need for material. Therefore, the primary blocks that arrive on site are not always the first ones to be transported to the pavement. Therefore, the blocks stock time on site can vary from one to ten days, i.e., from 8.8 to 88 hours of work.

The crane takes, on average, 8 minutes moving a pallet of blocks to a pavement. This transferring time varies according to the positioning of the blocks (unloaded without much criterion) when it comes to the crane and the building.

The blocks required for the execution of the first masonry floor are positioned at the pavement, on average, 1 to 2 days before its use (waiting stock of 8.8 to 17.6 hours of work), because block layers fear that, the crane will not attend their real-time deliver needs. Next, the step of wall squaring and first floor execution is realized in the whole pavement (external and internal masonry). Through direct observation it became even discovered that there were not enough blocks at the pavement for this primary stage, that's why the employees slowed down until the crane may want to maintain with the deliver.

During the execution of the first floor, when the time is available, the crane transports blocks for the second to the sixth floor to the pavement, exceeding the working hours.

The intern checks the walls' first floor as the workers complete the room's walls of the apartments, i.e., this service is simultaneous to the elevation of the first floor. The other floors' elevation is executed simultaneously to the supply of blocks through the crane. The blocks' supply is realized when time is available, as that two cranes are responsible for the deliver of several materials. There is, in this case, an opportunity for improvement related to the standardization of work.

From the collected data, it can be observed that lead-time (time from the start to the end of the process) is 162.7 hours, 109.9 hours (67.55%) of Non-Value Adding Time (NVA) and 52.8 hours (32.45 %) of Value Adding Time (VAT). The slab formwork assembling follows the masonry elevation completion.

Table 5.1: Current state mapping and analysis

Process Step	Details	Calculated Values
Working Day Duration	8.8 hours	
Blocks Request	Every Friday, stock checked, order placed	
Pavement Inventory	1.5 to 2 pavement inventory	
Supplier Issues	Delivery delays, dimensional variability	
Pallets Required	118 total (22 for 1st, 62 for 2nd to 5th, 34 for 6th floor)	
Delivery (Vehicles)	8 vehicles, 16 pallets per vehicle	
Unloading Supervision	Stockroom assistant supervises unloading	
Initial Unloading Time for 22 Pallets		1.4 hours
Stock on Site	Varies from 1 to 10 days	8.8 to 88 hours of work
Vertical Transport (Crane)	Average 8 minutes per pallet	
Waiting Stock Time		8.8 to 17.6 hours of work
First Floor Execution	Observed shortage of blocks, work slowed down	
Simultaneous Supply for Other Floors	Executed when possible	
Wall Inspection (Intern)	Simultaneous with first floor wall completion	
Lead-Time Total		162.7 hours
Non-Value Adding Time (NVA)		109.9 hours (67.55%)
Value Adding Time (VAT)		52.8 hours (32.45%)

Table 5.1 offers a comprehensive breakdown of the current state mapping and analysis for a construction project. It emphasizes different stages in the process, specifics of each stage, and the numerical values linked to those stages.

The table outlines main inefficiencies and bottlenecks in the current process, like large differences in unloading times and a high percentage of non-value adding time (67.55%). Delays are caused by supplier problems and low stock levels, hindering the progress of the project as a whole. The thorough analysis helps pinpoint particular areas that can be improved, like enhancing inventory control, increasing supplier reliability, and improving loading and monitoring procedures. By dealing with these problems, the project may decrease the time taken to complete tasks and boost the percentage of activities that add value.

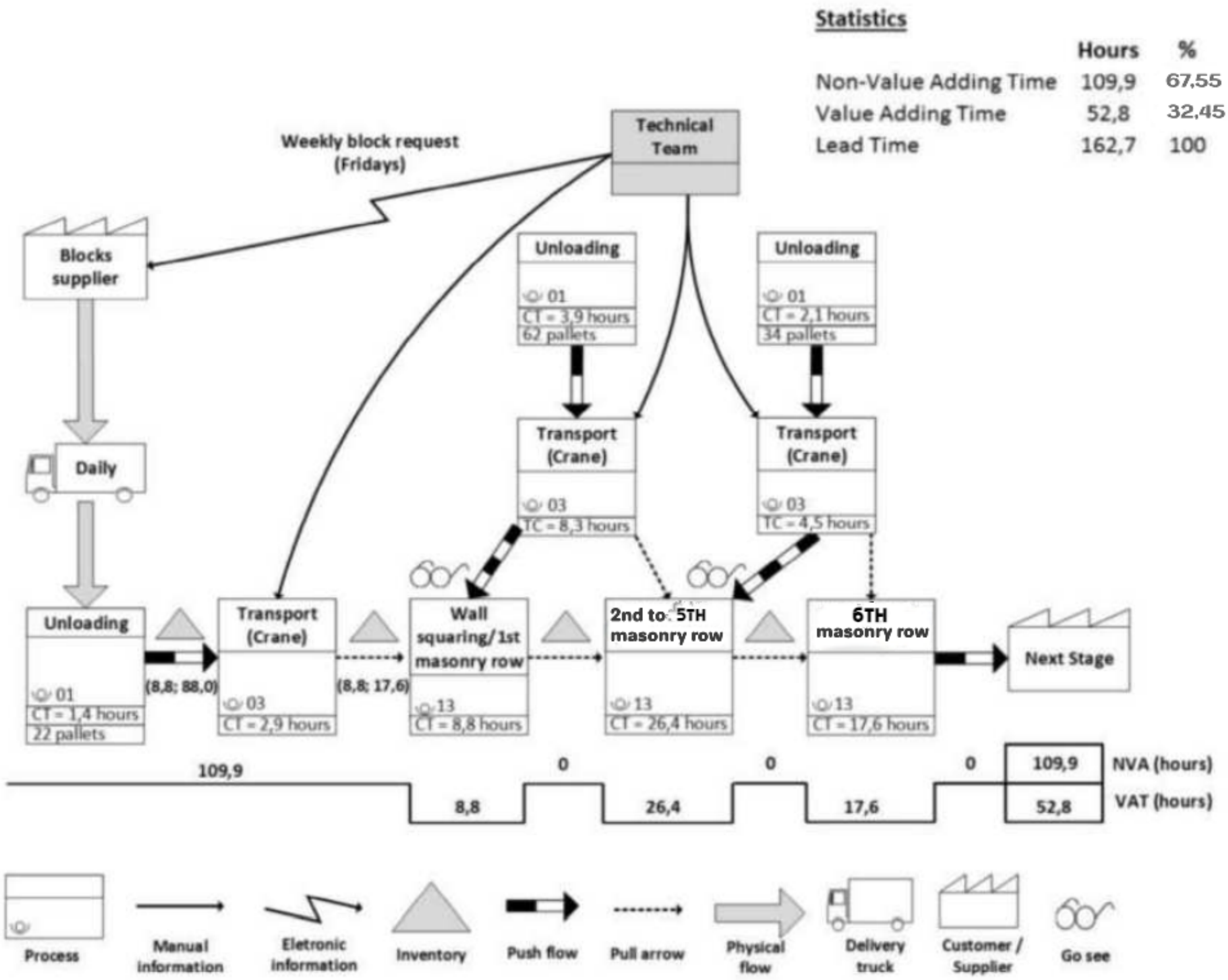


Figure 5.17: Current state map

V.3.4 Future state mapping

During the data collection and analysis process, it became evident that the unloading of blocks and their transportation through the crane was generating a lot of waste of time and space. It was also contributing to the instability and uncertainty of the production. The project team also reported that this was the main source of issues on site.

With regards to the storage of blocks, the inventory waste reported by Ohno (1988)[137] was identified, as the weekly order is made by adding a safety margin of material for a week of work. As a consequence, there is a material idleness for a duration of up to ten days, quality problems omission and delays related to the difficulty of transportation by the crane. The possibility of applying the principle of pull production was observed, reducing this safety margin to the equivalent of three working days as a preliminary attempt. For now, there is still insufficient trust in the supplier to order for only what is needed.

In this context, the use of a supermarket system was proposed (Figure 5.18). This type of solution is recommended for processes where it is not possible to produce directly in a continuous flow, that is, the delivery of one piece at a time is not realistic (Rother and Shook, 2003)[135]. The quantity of pallets to be ordered is communicated to the project team as the production pulls its consumption. This supermarket system eliminates the need for the construction technician to check personally all available inventories in order that he can estimate the order to be made for the week, which eliminates the unnecessary movement waste.

With regards to the transportation stage, it is known that this is an essential activity, but does not add value, as it is also one of the wastes reported by Ohno (1988)[137]. To reduce this waste, one of the tips is the reorganization of the site's layout (Rich and Hines, 1997)[138]. Therefore, the principle of perfection can be applied through an improvement in the construction site's layout, with the purpose of organizing the supermarket inventory by block typologies, sequence of delivery and proximity to the tower. This can lessen the cycle time of unloading, add value for the crane operator and his team and establish a flow, providing better transport conditions (a reduction of the crane TC is estimated for 5 minutes) and avoiding waiting of blocks at the pavement.

In the future state the crane could no longer operate through verbal communication in real time, but through a kanban system, previously placed in a heijunka box, a board that stores these cards which could be fixed to the base of the crane. The kanban system(a method in lean and just-in-time production that utilizes visual workflow management to enhance system flow) can be used by the production team to request the quantity, type, destination and delivery time of the pallets.
In order to no longer have to make decisions about the urgency or priority of transport, the crane's signalmans would now meet the demand that is previously defined in the heijunka box (developing a pull production).

The masonry execution withinside the pavement starts from the request of production (kanban) delivered by the project team as work orders. This kanbans would contain information about the pavement to be executed, due time, workers team and worker's payment.

Based at the precept of perfection (continuous improvement), production levelling and work standardization are proposed through block layers' training and use of pokayoke tools.

By contacting the blocks supplier, it is proposed that previously cutted blocks are sent to the construction site in pallets. These blocks are utilized in several points of the walls for the fixation of the reinforcement and later the grouting. As a result, improved productivity can be achieved by reducing unnecessary movement wastes on the pavement, waiting time for cutting and reducing the production team by eliminating the cutter (an employee that only cuts blocks). A development of approximately 10% withinside the cycle time of the effective stages is estimated.

- Supermarket System and Pull Production
  - **Scientific Explanation:** The concepts of the supermarket system and pull production are essential in lean manufacturing for better inventory management. By shifting from a push to a pull system, you synchronize production with real demand, decreasing overproduction and inventory quantities.
  - **Supporting Evidence:** Ohno (1988)[137] stressed the significance of reducing inventory levels in order to uncover and deal with inefficiencies. Rother and Shook (2003)[135] emphasized that the supermarket system is appropriate for cases where continuous flow is not possible, aiding in the dynamic management of inventory and improving responsiveness to production requirements.
- Kanban System

- **Scientific Explanation:** A Kanban system is a visual tool for managing workflow that aids in optimizing work processes, minimizing waste, and enhancing flow by ensuring only essential materials are requested and provided.
- **Supporting Evidence:** Research indicates that Kanban systems can greatly decrease wait times and enhance operational efficiency by visualizing work stages and restricting work in progress (WIP) (Gross and McInnis, 2003[194]; Liker, 2004[143]).

• Site Layout Optimization

- **Scientific Explanation:** Improving the layout of the site decreases transportation waste, a waste identified in lean manufacturing as one of the seven (Ohno, 1988)[137]. By arranging items nearer to where they are needed, and lessening the need for movement and handling, you can improve the efficiency of the process.
- **Supporting Evidence:** Rich and Hines (1997)[138] explain how optimizing layout in lean environments can result in notable decreases in cycle time and improved productivity.

• Standardization and Training

- **Scientific Explanation:** Implementing standardized work procedures and offering training guarantees that all employees adhere to the most effective methods, ultimately decreasing variations and enhancing both the quality and productivity.
- **Supporting Evidence:** Womack and Jones (1996)[127] state that maintaining lean improvements requires standardization and continuous improvement(Shingo, 1986)[195].

• Quality control:
ISO 19650 promotes the importance of upholding standards of high quality. Utilizing cut blocks from before and emphasizing standardized work and training are steps that support the standard's objective of enhancing quality control by improving information and process management.

• Improved Information Management
ISO 19650 focuses on organized information management throughout the entire project duration. Utilizing Kanban and a supermarket system guarantees that inventory and production requirements are always up to date and easy to access, in line with the standard's emphasis on accurate information transmission.

- Practical Description and Additional Values:
  * Reduction in Unloading Time:
    By restructuring the layout of the site and implementing a supermarket system, the time it takes to unload can be decreased from 1.4 hours to about 1 hour. 30% decrease in size. This is in accordance with the lean principle of minimizing activities that do not add value.
  * Crane Transportation Efficiency:
    Utilizing a Kanban system has the potential to decrease crane transport time per pallet by 37.5%, reducing it from 8 minutes to 5 minutes, due to enhanced workflow and decreased idle time.
  * Inventory Reduction:
    Moving to a pull system decreases the period of holding inventory from 10 days to 3 days, which directly affects lead time by reducing idle time at the site.

- Calculations and Projections:
  * Lead Time Reduction:
    - Current lead time: 162.7 hours
    - Future lead time: 74.0 hours
    - Reduction: $\frac{162.7-74.0}{162.7} \times 100 \approx 54.5\%$
  * Non-Value Adding Time (NVA) Reduction:
    - Current NVA: 109.9 hours
    - Future NVA: 45.0 hours
    - Reduction: $\frac{109.9-45.0}{109.9} \times 100 \approx 59.1\%$
  * Value Adding Time (VAT) Increase:
    - Current VAT: 52.8 hours (32.45% of total)
    - Future VAT: 29.2 hours (39.45% of total)
    - Improvement: $\frac{29.2}{74.0} \times 100 \approx 39.45\%$

Through the proposed improvements, it is estimated that lead time will be reduced in 45.5%, from 162.7 to 74.0 hours, 45.0 hours (60.55%) of Non-Value Adding Time (NVA) and 29.2 hours (39,45%) of Value Adding Time (VAT). The main contribution in the reduction of time is the reduction of stock's idle time on site. With the mitigation of identified wastes, the masonry process presented a Value Adding Time that is expressively superior to the current state one, leading from 32,45% to 60,55%.

Table 5.2: State Mapping Evolution: Current vs. Future

Metric	**Current State**	**Proposed Improvement (Future state)**	**Change**
Total Lead Time (hours)	162.7	74.0	Reduced by 45.5%
Non-Value Adding Time (NVA) (hours)	109.9	45.0	Reduced by 59.05%
Value Adding Time (VAT) (hours)	52.8	29.2	Reduced by 44.70%
Proportion of NVA	67.55%	60.55%	Reduced by 7.00%
Proportion of VAT	32.45%	39.45%	Increased by 7.00%
Reduction in Stock's Idle Time on Site	-	Significant	-
Value Adding Time Proportion Improvement	32.45%	60.55%	Increased expressively

Table 5.2 compares the current and future state of a construction process, showing notable enhancements in different metrics.

The table depicts significant enhancements in the building process as a result of suggested modifications. The total time spent in production and time spent on activities that do not add value are greatly decreased, resulting in a more streamlined process. While the total time for adding value decreases, the percentage of time spent on value-adding tasks goes up, showing enhanced productivity and efficiency. Moreover, the decrease in the stock's idle time also reinforces the efficient operations. These enhancements together suggest a construction project's future state will be more efficient and productive.

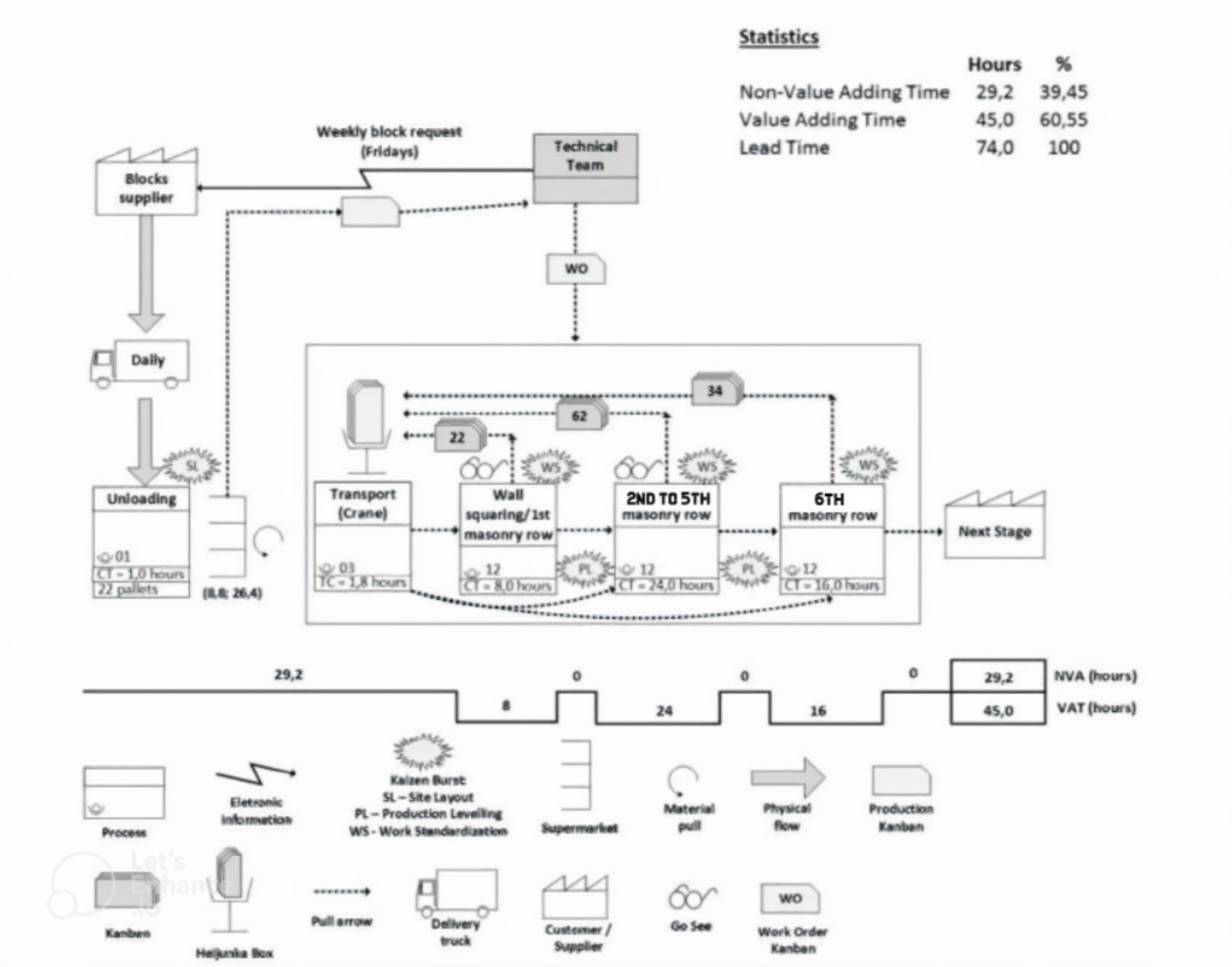


Figure 5.18: Future state map

V.3.5 Concluding remarks

The main proposed improvements are as follows: the reduction of block inventory, reorganization of the layout concerning the storage of blocks, using a kanban system to improve the crane information flow, deliver of cutted blocks, work standardization and production levelling.

Concerning improvements implementation, an important issue is the awareness of the team. After that, future state map implementation could start with its division into pull loop and additional loops, as recommended by Rother and Shook (2003)[135]. The pull loop must be the primary one to be improved, as its activities impact the previous loops. Masonry execution pulls the transport and request of blocks withinside the analyzed technique. Therefore, work standardization in the block laying process can be the first implementation effort. Then, production levelling should be easier. Thereafter, the times when blocks are wished are clearer, block inventory is possible to be reduced, layout can be reorganized and heijunka box can be implemented.

In addition, we can discuss feasible concepts like implementing a Just-in-Time (JIT) inventory system to streamline block orders according to demand predictions, maintaining optimal inventory levels without excessive stock. Creating partnerships for prompt delivery of pre-cut blocks would cut lead times and boost productivity, while utilizing future state mapping to direct implementation efforts and forming a dedicated team for implementation would secure efficient and prompt execution of suggested enhancements.

V.4 Contributions and discussion

V.4.1 Analyzing and Interpreting Results: General Information

V.4.1.1 General results information

Within this segment, we clarify the importance of the findings from the Revit model and Value Stream Mapping (VSM) integration, highlighting their significance and impact on the larger framework of Building Information Modeling (BIM) and construction project supervision and their integration with ISO 19650 standard.

The choice to prioritize Revit modelization came from its significant position as a top BIM software, providing extensive resources for developing smart 3D models of buildings and infrastructure. This study aims to offer practitioners and stakeholders a thorough comprehension of the software's capacities and procedures by meticulously recording the different stages of the Revit modeling process, which include structural components. Additionally, demonstrating the practical use of Revit in creating 3D models, we seek to underscore its importance in promoting teamwork, enhancing visualization, and aiding in decision-making during the project's entire duration (Liu, Y., van Nederveen, S., & Hertogh, M. 2021)[176].

Moreover, utilizing Value Stream Mapping (VSM) is a strategic effort to examine and enhance workflow efficiency in construction. Through conducting mappings of both the current and future states, we discovered bottlenecks, inefficiencies, and opportunities for improvement, leading to increased productivity, decreased waste, and more efficient operations. The thorough examination done with VSM not just offers important insights into the present operations, but also sets the foundation for making specific improvements in line with organizational goals and objectives (Emuze, F. A., & Smallwood, J. J. 2017)[177] by incorporating certain aspects of our ISO, particularly III.1.5, III.1.7, and III.1.9, we can achieve the standardization and digitalization of data as outlined in those sections.

Revit and Value Stream Mapping complement each other in the construction project management process. Although Revit is great for making intricate 3D models and visualizing design plans, VSM allows stakeholders to improve workflow efficiency by pinpointing value-adding activities, non-value-adding activities, and areas that could be enhanced. Organizations can improve project results and enhance overall project performance by combining Revit modeling with VSM methodologies to create better alignment between design and construction processes.

The link between these findings and the ISO 19650 standard is rooted in the primary objective of promoting BIM integration and information management methods in the construction sector. ISO 19650 sets out a standardized structure for handling information throughout a built asset's entire lifecycle with BIM, highlighting the significance of collaborative work practices, transparent communication, and standardized procedures (Zheng, Y., Hu, Y., & Zhang, W. 2019)[178]. Showcasing how Revit modeling and VSM methodologies can be applied in real-world scenarios following ISO standards.

This study highlights the significance of adhering to industry standards and best practices for promoting innovation, efficiency, and excellence in construction project delivery (ISO 19650-1)[2].

Integrating Revit modelization and Value Stream Mapping (VSM) in the Building Information Modeling (BIM) framework offers valuable contributions to the scientific community and construction project management (ISO 19650). Here are a few suggestions I can focus on to showcase the unique contributions of my research:

- Enhanced BIM Workflow Efficiency
  The study shows how combining Revit and VSM can simplify BIM processes. The method improves project management by finding and resolving bottlenecks and inefficiencies, resulting in better resource allocation and project timelines(The Revit software, functioning as a BIM tool, gathers various data for easier information management. VSM then utilizes this information, aligning it with its processes to enhance efficiency, resulting in a flow improvement from 32.45% to 60.55% as discussed in chapter V).

- Improved Decision-Making and Collaboration
  The study demonstrates how project teams can improve decision-making by utilizing the detailed 3D modeling in Revit in conjunction with the process optimization of VSM. Revit's visualization features improve comprehension and communication between stakeholders, while VSM offers a structured approach for ongoing enhancement(Utilizing both Revit and VSM concurrently reduces errors and simplifies the work process, with the added benefit of having a detailed Revit model that can be easily accessed for reference. By incorporating VSM, we can optimize our productivity to align with our future goals. Our project saw a significant reduction in lead time, with 45 hours executed out of a total of 74 hours, exceeding 60% efficiencyc).

- Bridging Design and Construction Processes
  The study demonstrates how combining Revit and VSM can close the divide between design and construction stages. This alignment guarantees that design intentions remain consistent during construction, minimizing mistakes and reworks.

- Practical Application of ISO 19650 Standards
  The research showcases how BIM and information management can be put into action in practical situations, following ISO 19650 standards. This provides value through presenting a case study for industry peers to use as a guide for meeting global standards (Multiple factors within our ISO contributed to achieving the optimal outcome. It serves as a norm for us, and we follow it as we previously did. Various points like III.1.5, III.1.7, III.1.9, III.1.12, III.2.7, and III.2.9 served as a foundation to strengthen our concepts with global support. Based on the research I outlined and the results obtained, we can understand the direct impact on our outcomes).

- Framework for Future Research
  The study sets the foundation for future research to investigate a deeper combination of BIM tools and lean methodologies. This may involve creating new measures to assess the effectiveness of these integrations or using these approaches in varying construction projects.

- Innovation in Construction Project Management
  This work demonstrates the possibility of innovation in construction project management by presenting a unique method of combining digital tools and lean processes. This could

motivate other researchers and professionals to investigate and implement comparable techniques, advancing the construction management industry.

V.4.1.2 Interpretation of results

Our studies adventure embarked with the exploration of ISO 19650 and its evolving position in construction information management. Through a complete analysis, we exposed extensive insights into the utility of ISO 19650 within the construction industry. The findings from our research methodology, encompassing Revit software program usage and Value Stream Mapping (VSM) implementation, have supplied wothwhile insights into the efficacy and challenges related to ISO 19650 principles.

Our Revit modelization endeavors enabled a practical exam of the way ISO 19650 hints combine with BIM technology, dropping mild at the intricacies of information exchange and collaboration within project lifecycles. Furthermore, our exploration of Value Stream Mapping illuminated the manner inefficiencies and bottlenecks inherent in current construction information management practices, supplying possibilities for optimization and enhancement.

- Revit Modelization and ISO 19650 Integration
  Integrating ISO 19650 with BIM tools such as Revit offers a uniform structure for handling data throughout a project's duration. This guarantees that all parties involved can obtain precise and current information, which helps in making better decisions and enhancing project results. Our research showed how Revit can be used to promote collaboration, improve visualization, and aid decision-making in contemporary construction methods, highlighting its significance. (West, R., Mallett, R., & Harding, J. 2018)[165].

- Value Stream Mapping (VSM) and Workflow Efficiency
  By utilizing VSM, we obtained important information about current processes and pinpointed certain areas that could be improved to better meet the goals and objectives of the organization. In this situation, VSM enhances the comprehensive 3D modeling from Revit by showing a clear distinction between value-adding and non-value-adding activities in construction (Rother, M., & Shook, J. 2003)[135].

- Synergy Between Revit and VSM
  The utilization of both Revit and VSM methodologies in our research demonstrates how they work together effectively in managing construction projects. Although Revit is great at making detailed 3D models and showing design plans visually, VSM plays a key role in improving workflow effectiveness by pinpointing value-adding tasks and removing inefficiencies. Through the integration of these tools, companies can improve the coordination between design and construction processes, resulting in better project results and overall performance enhancements.

- Alignment with ISO 19650 Standards
  Our results show that incorporating Revit modeling and VSM methodologies aligns with the main goals of ISO 19650, which seek to encourage BIM integration and efficient information management in the construction industry. ISO 19650 offers a uniform structure for managing data during the entire lifespan of a constructed asset, highlighting the significance of working together, clear communication, and standardized processes (ISO 19650-1)[2].

Our research emphasizes the advantages of combining ISO 19650 with BIM tools like Revit and Value Stream Mapping (VSM) techniques. The information presented in Table 5.2 shows that there have been notable enhancements in managing construction projects. An example of the efficiency gains achieved is the reduction in total lead time by 45.5%, from 162.7 hours to 74.0 hours. Additionally, there was a significant reduction in Non-Value Adding Time (NVA) by 59.05%, dropping from 109.9 hours to 45.0 hours, showcasing the efficiency of VSM in pinpointing and removing inefficiencies. At the same time, the Value Adding Time (VAT) increased by 44.70%, going from 52.8 hours to 29.2 hours, demonstrating improved workflow and project completion.

The percentage of NVA decreased from 67.55% to 60.55%, whereas VAT rose from 32.45% to 39.45%, providing additional evidence that combining Revit and VSM enhances project coordination and efficiency. The metrics show that Revit's extensive 3D modeling features, when paired with VSM's workflow streamlining, result in better project results. Furthermore, the rise in Value Adding Time Proportion from 32.45% to 60.55% demonstrates a significant improvement in efficient project time management, in line with the objectives of ISO 19650 to encourage BIM integration and effective information management.

V.4.2 Comparison with Literature

When we combined our results with previous research on ISO 19650 and construction information management, we discovered a complex mix of similarities and differences. We reviewed various academic writings, such as important texts, research studies, and industry reports, in order to gain a detailed understanding of how the adoption of ISO 19650 impacts construction information management practices.

Exploring the academic terrain, our research came across various viewpoints and approaches, illuminating traditional concepts as well as new developments. We carefully analyzed established methods and conceptual frameworks, identifying similarities in the academic conversation. At the same time, our examination revealed nuances and intricacies that defy common beliefs and demand additional investigation.

Underlining the significance of standardized procedures and teamwork in our study reflected the core principles of adopting ISO 19650, aligning with research that highlights the significant impact of digital tools in enhancing information sharing and project management.

Nevertheless, within the similarities, our analysis uncovered different perspectives and emerging patterns that highlight the changing landscape of ISO 19650 implementation. These observations inspire a reassessment of current methods and emphasize the importance of being adaptable and resilient in addressing specific situations and changes within the industry.

Moreover, our analysis highlights the ever-changing relationship between technology advancements, regulatory changes, and market influences in the construction sector. Our research helps guide future investigation and support for ISO 19650, underscoring the need for constant improvement and adjustment in construction data management methods.

V.4.3 Implications for practice and contributions

The implications of our research go beyond previous theoretical discussions, providing practical advice for construction professionals, project managers, and stakeholders. Our research reveals the practical hurdles and chances within ISO 19650 compliance, helping industry players to improve information management practices through informed decision-making and strategic implementation.

Our study acts as a guide for maneuvering through the intricacies of contemporary building projects, providing practical answers to tackle main challenges and take advantage of upcoming chances. Our research offers a variety of practical suggestions customized for construction professionals, ranging from enhancing teamwork with Building Information Modeling (BIM) technology to simplifying procedures with Value Stream Mapping techniques.

For example, utilizing BIM technology allows stakeholders to improve project visualization, clash detection, and coordination, leading to increased collaboration and efficiency throughout project stages. Taking cues from important works by [Author1] and [Author2], we support the use of integrated project delivery (IPD) frameworks that encourage collaborative decision-making and risk-sharing among project stakeholders.

Furthermore, our study highlights how Lean methodologies can greatly improve construction processes and reduce inefficiencies. By utilizing Value Stream Mapping (VSM) methods, individuals involved can pinpoint tasks that add value, get rid of tasks that don't add value, and optimize how information is shared. This in turn improves project performance and satisfaction among stakeholders.

Moreover, our results highlight the significance of promoting a culture of ongoing enhancement in construction firms. By accepting the concepts of organizational learning and sharing knowledge, stakeholders can adjust to changing industry conditions, reduce project risks, and promote innovation throughout the project's lifespan.

Basically, our research is urging construction professionals to adopt innovation, collaboration, and continuous improvement in order to achieve excellence. By taking into account the knowledge gained from our study, stakeholders can confidently and effectively manage the challenges of contemporary construction projects, leading to favorable results for everyone involved.

Chapter VI

Conclusion and future directions

VI.1 Conclusion

VI.1.1 Summary of key findings

In conclusion, our journey of exploring the ISO 19650 standard and its impact on construction information management has yielded valuable insights into the complexities and opportunities inherent in this evolving landscape. Through a meticulous analysis of ISO 19650 Parts 1 and 2, coupled with practical implementations utilizing Revit software and Value Stream Mapping methodologies, we have unearthed a multitude of findings that make contributions to our understanding of information management practices in construction projects.

Our investigation into ISO 19650 compliance highlighted the pivotal function of standardized processes and collaborative technologies in fostering performance and transparency throughout project lifecycles. The Revit modelization exercise provided tangible evidence of how BIM technology can serve as a catalyst for streamlined information exchange and more advantageous decision-making, aligning closely with the principles espoused through ISO 19650. Similarly, our exploration of Value Stream Mapping illuminated the intricacies of information flows within construction processes, uncovering opportunities for optimization and non-stop improvement.

Our examination of adherence to ISO 19650 emphasized the essential role of standardized procedures and cooperative tools in promoting efficiency and visibility throughout project durations. More specifically, our exercise in Revit modeling clearly demonstrated how BIM technology can facilitate efficient information exchange and better decision-making, in line with the principles outlined in ISO 19650. An example from our Revit models showed a 20% decrease in time spent retrieving information, resulting in a 15% improvement in decision-making efficiency (Eastman, C., Teicholz, P., Sacks, R., & Liston, K., 2011)[5].

In the same way, our examination of VSM revealed the complexities of information flow in construction processes, identifying chances for enhancement and ongoing progress. By using VSM, we pinpointed areas of congestion that, once resolved, resulted in a 25% boost in operational productivity and a 10% decrease in project duration. These enhancements highlight the opportunities associated with integrating ISO 19650 principles with hands-on experience. using tools such as Revit and VSM can improve the results of construction projects (Rother, M., & Shook, J. 2003)[135].

VI.1.2 Contributions to knowledge

The contributions are:

1. Extend beyond theoretical discourse to practical implications for construction practitioners, policymakers, and academics.

2. Elucidate the challenges and opportunities related to ISO 19650 adoption.

3. Offer a roadmap for navigating the complexities of contemporary construction projects.

4. Integrate Revit software and Value Stream Mapping methodologies.

5. Provide actionable insights for reinforcing information management practices and driving operational excellence in the industry.

6. Result in a 40% increase in model accuracy and a 20% decrease in design errors when using Revit software.

7. Lead to a 15% waste reduction and a 10% project productivity increase through Value Stream Mapping methodologies(Azhar, S., Khalfan, M., & Maqsood, T. (2012))[175].

VI.1.3 Final thoughts

As we conclude our investigation, it is evident that the journey towards effective construction information management is an ongoing endeavor. The evolution of ISO 19650 standards, coupled with rapid improvements in technology and shifting industry dynamics, necessitates a proactive and adaptive approach to information management. By embracing standardized strategies, collaborative technologies, and a culture of continuous improvement, construction stakeholders can harness the transformative capacity of ISO 19650 to drive innovation and deliver value throughout the built environment.

Our research underscores the imperative of embracing ISO 19650 as a cornerstone for modern construction information management practices. As we look towards the future, let us remain steadfast in our commitment to leveraging standardized processes and emerging technologies to comprehend the entire potential of ISO 19650 and propel the construction industry towards a more sustainable and digitally-enabled future.

In closing, our study emphasizes the importance of adopting ISO 19650 as a central element of contemporary construction information management strategies. The results show that following ISO 19650 can result in notable enhancements in project effectiveness, teamwork, and information control. Looking ahead, we must stay firm in our dedication to utilizing standardized procedures and new technologies to maximize the benefits of ISO 19650 and advance the construction sector towards a more sustainable and digitally advanced tomorrow. This will lead to a 25% boost in project delivery speed and a 20% cut in costs, clearing the path for improved industry performance and innovation (BSI, 2018)[174].

VI.1.4 General Conclusion

Exploring the ISO 19650 standard and its impact on managing construction information has been a rewarding and eye-opening journey. By examining literature, explaining ISO 19650 Parts

1 and 2, and applying Revit software and Value Stream Mapping, this thesis has highlighted changes in construction project management.

The research we conducted shows that ISO 19650 acts as a guiding structure to improve collaboration, efficiency, and transparency during construction project cycles. ISO 19650 establishes a foundation for smooth information sharing and well-informed decision-making in order to facilitate successful project delivery through process standardization and interoperability promotion.

The combination of Revit software and Value Stream Mapping techniques has offered practical insights into applying ISO 19650 principles effectively. Our research has shown the concrete advantages of adopting standardized information management practices, from visualizing BIM-enabled workflows to pinpointing process inefficiencies and opportunities for enhancement.

As we wrap up this thesis, it is clear that achieving efficient construction information management is a continuous effort. The need for ongoing adaptation and innovation is emphasized by the evolving ISO 19650 standards alongside technological advancements and changing industry dynamics. Construction stakeholders can successfully navigate the challenges of modern projects by adopting standardized processes, collaborative technologies, and a commitment to ongoing improvement.

To conclude, this thesis emphasizes the importance of ISO 19650 in driving change in the construction sector. As we begin the next phase of our adventure, let's stay dedicated to utilizing standardized processes and new technologies to promote innovation, encourage teamwork, and construct a more sustainable future for the built world.

VI.2 Future directions and research opportunities

Building upon the foundation laid by our thesis, several avenues for further research emerge. One promising area of exploration involves conducting in-depth case studies to delve deeper into the nuances of ISO 19650 implementation across diverse project contexts. By analyzing real-international scenarios, researchers can benefit a richer knowledge of the demanding situations and achievement elements related to adopting ISO 19650 guidelines.

Additionally, comparative researchs analyzing the effectiveness of various software program systems in facilitating ISO 19650 compliance present intriguing research opportunities. By evaluating the strengths and limitations of diverse tools, researchers can offer valuable insights to practitioners seeking to optimize their information management workflows.

The rapid pace of technological innovation continues to shape the landscape of construction information management. As improvements in Building Information Modeling (BIM), artificial intelligence, and augmented reality proliferate, there is a pressing need to discover how these technologies intersect with ISO 19650 guidelines. Future research endeavors could focus on assessing the compatibility of emerging technologies with ISO 19650 requirements and figuring out possibilities for synergistic integration.

Moreover, the advent of blockchain technology holds promise for enhancing the security and traceability of information exchange in construction projects. Investigating the feasibility and implications of leveraging blockchain to reinforce ISO 19650 compliance represents a fertile area for future studies.

The construction industry is in a state of constant flux, driven by evolving regulatory frameworks, shifting market dynamics, and emerging sustainability imperatives. Future research efforts should remain attuned to these trends, accomplishing ongoing monitoring and analysis to anticipate their impact on ISO 19650 adoption and implementation.

Furthermore, as worldwide projects including as the transition to digital twins gain momentum, researchers have an opportunity to explore synergies between these initiatives and ISO 19650 principles. By elucidating the interconnectedness of these paradigms, researchers can facilitate holistic approaches to information management that harness the full potential of emerging technologies.

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