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BUILDINGS BIM LIBRARY MANAGEMENT PLATFORM
PROJECT

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Lofty heights, lofty dreams, headed out unto the realms of uncertainty where days turned into months and months into a year – the camaraderie of shoulders belonging to citizens of countries far and wide, we all came together as the BIM A+ family to share the knowledge and to grow in purpose – to each one of you I wish those sleepless nights had brought you closer to your desires. Thank you

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Finally, to anyone reading this project, I hope you find strength in your faith, inspiration in your heart and direction on your path to do something great.

.....

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I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

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SOMMARIO

Nel panorama in continua evoluzione dell'industria dell'architettura, dell'ingegneria, delle costruzioni e delle operazioni (AECO), la collaborazione efficiente tra le diverse parti interessate è fondamentale. Il Building Information Modelling (BIM) è emerso come uno strumento vitale per semplificare lo scambio di informazioni in questo complesso ecosistema. Al centro del flusso di lavoro BIM si trova la libreria BIM, un archivio di oggetti BIM standardizzati e ricchi di dati. Queste librerie migliorano l'efficienza fornendo elementi riutilizzabili e standardizzati che promuovono la collaborazione e riducono le ridondanze. Questa ricerca è dedicata alla formulazione di linee guida per una libreria BIM adattata alle esigenze specifiche di una società di progettazione, ingegneria e costruzione su larga scala. Il suo obiettivo centrale è quello di colmare il crescente divario tra le parti interessate tecniche e non tecniche, democratizzando l'accessibilità dei dati. Assicurando che i dati cruciali siano prontamente disponibili e comprensibili per tutti, questo studio mira a coltivare l'inclusività e la collaborazione. Gli obiettivi della ricerca comprendono l'analisi del flusso di lavoro, l'identificazione dei colli di bottiglia e delle inefficienze nei processi BIM, la valutazione dell'archiviazione e del recupero degli oggetti BIM, l'indagine completa di casi studio e la sintesi dei risultati per sviluppare linee guida onnicomprensive per una biblioteca di oggetti BIM appositamente costruita. I risultati principali sottolineano l'eccessiva dipendenza dalle competenze tecniche, che porta a colli di bottiglia per le parti interessate non tecniche. L'analisi dei documenti e il feedback degli utenti evidenziano l'imperativo di ottimizzare l'esperienza dell'utente, migliorare l'accessibilità agli oggetti BIM e facilitare gli aggiornamenti in tempo reale. L'analisi dei casi studio avvalorano ulteriormente questi risultati, rivelando le metriche chiave per lo sviluppo di una piattaforma di gestione delle librerie BIM. Questi parametri comprendono l'interfaccia utente, la funzionalità di back-end, la collaborazione e l'interazione, l'autenticazione degli utenti e il controllo degli accessi, il pannello di amministrazione e l'integrazione con strumenti esterni. Lo studio raccomanda l'implementazione di questi requisiti insieme a una documentazione tecnica completa e al monitoraggio, alla valutazione e alle valutazioni tecniche costanti per lo sviluppo della piattaforma. La ricerca solleva anche domande interessanti sulla potenziale evoluzione degli oggetti BIM intelligenti e sulla loro incorporazione nelle librerie BIM, aprendo le porte all'esplorazione di tecnologie immersive come AR, VR e XR. In sintesi, questo studio rappresenta un riferimento prezioso per le organizzazioni del settore AECO che cercano di stabilire o ottimizzare le loro piattaforme di gestione delle librerie BIM dedicate.

Parole chiave: Libreria BIM, Oggetti BIM, Building Information Modelling, Collaborazione, Piattaforma di gestione BIM

ABSTRACT

In the ever-evolving landscape of the Architecture, Engineering, Construction, and Operations (AECO) industry, efficient collaboration among diverse stakeholders is paramount. Building Information Modelling (BIM) has emerged as a vital tool for streamlining information exchange in this complex ecosystem. At the heart of the BIM framework lies the BIM library, a repository of standardized and data-rich BIM objects. These libraries enhance efficiency by providing reusable, standardized elements that promote collaboration and reduce redundancies. This research is dedicated to formulating guidelines for a BIM library management platform tailored to the specific needs of a large-scale design, engineering, and construction company. Its central aim is to bridge the growing gap between technical and non-technical stakeholders by democratizing data accessibility. By ensuring that crucial data is readily available and comprehensible to all, this study aims to cultivate inclusivity and collaboration. The research objectives encompass workflow analysis, identification of hindrances and inefficiencies in BIM processes, assessment of BIM object storage and retrieval, comprehensive case study investigation, and synthesis of findings to develop comprehensive guidelines for a purpose-built BIM library management platform. Key findings underscore the overreliance on technical expertise, which leads to bottlenecks for non-technical stakeholders. Insights from document analysis and user feedback highlight the imperative for optimizing the user experience, enhancing BIM object accessibility, and facilitating real-time updates. Case study analysis further substantiates these findings by revealing key metrics for the development of a BIM library management platform. These metrics encompass User Interface, backend functionality, collaboration and interaction, user authentication and Access Control, Administration Panel, and Integration with external tools. The study recommends the implementation of these requirements along with technical documentation, ongoing monitoring, evaluation, and technical assessments for the platform development. The research also raises intriguing questions about the potential evolution of intelligent BIM objects and their incorporation into BIM libraries, opening doors for the exploration of immersive technologies like AR, VR, and XR. In sum, this study stands as a valuable reference for AECO industry organizations seeking to establish or optimize their dedicated BIM library management platforms.

Keywords: BIM Library, BIM Objects, Building Information Modelling, BIM Management platform, Collaboration

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1. INTRODUCTION

The design process for artifacts within the Architecture, Engineering, Construction, and Operations (AECO) industry demands collaboration and oversight from multiple stakeholders, each possessing their unique expertise. Prior to the digital era, these procedures relied on traditional paper-based documentation methods, including drawing sets, proposals, review documents, and various project-related requisites to share and transfer information. To bridge this gap, Building Information Modelling (BIM) plays a crucial role in enhancing information exchange between stakeholders engaged at various stages, thereby boosting efficiency by eliminating the tedious and error-prone manual data transfer prevalent in traditional paper-based processes. Public and private institutions alike are employing the BIM methodology for better project lifecycle managements however at different adoption level. Though numerous, one of the essence of BIM is its ability to provide a cohesive and dynamic platform for stakeholders to collaborate while leveraging a shared digital representation of the asset throughout its lifecycle.

As organisations strive to fully realise the benefits of BIM, one critical aspect emerges: the BIM Object library, a repository of digital assets at the heart of the BIM ecosystem. BIM Object libraries are critical components of the Building Information Modelling (BIM) ecosystem that houses BIM objects – a standardized and data-rich format for representing building components. Their significance stems from their ability to improve and streamline various aspects of the construction process giving professionals a catalogue of reusable standardised elements that foster collaboration, reduce redundancies, and improves overall efficiency of the BIM methodology.

The NBS National BIM Library as an example highlight some positives of its library – more accurate project modelling, specifications, costings, and quantities, but also better information management for future maintenance and sustains BIM throughout the building's lifetime (NBS, 2017). According to (Hannell, 2016), the inclusion of a comprehensive object library significantly impacts the quality and efficiency of modeling processes, rendering it an indispensable element in achieving profitable and successful project deliveries. Conceptually, one can liken a BIM object library to a meticulously organized 'kit of parts' on an assembly line. When a designer, engineer, architect, or modeler can promptly locate an object within this library, effortlessly integrating it into the model, substantial time savings are realized. This streamlined process translates to the preservation of hours, days, or even weeks of work. Furthermore, the reusability of these objects across multiple projects amplifies these efficiency gains.

Generally, BIM libraries are crucial to foster collaboration by providing a standardized platform where architects, engineers, contractors, and other stakeholders can access and integrate pre-modelled components – BIM Objects into their designs. However, due to differing organisational requirements, disciplines, workflows and the advent of several BIM software solutions, an organisation needs to develop its own BIM library management platform tailored to its preferences.

The primary aim of this research is to comprehensively analyse the operational processes within a large-scale design, engineering, and construction company. The overarching goal is to derive a comprehensive design guidelines for the development of a BIM library management platform tailored to the specific needs of the organization.

To fulfil the research purpose effectively, the following specific objectives have been delineated:

1. **Workflow Analysis:** Conduct a systematic observation and analysis of the current workflow within the organization to gain an in-depth understanding of its BIM processes, identifying bottlenecks, inefficiencies, and areas for improvement.
2. **BIM Object Storage and Retrieval Assessment:** Evaluate the existing BIM object storage and retrieval system employed by the company, focusing on its efficiency, optimisation, and alignment with intended improvement.
3. **Case Study Investigation:** Undertake an extensive case study analysis of similar BIM object libraries utilized in public domain to extract valuable insights, benchmark against industry standards, and identify best practices.
4. **Guideline Development:** Synthesize the findings from the other objectives to develop comprehensive guidelines for the creation and management of a purpose-built BIM library management platform, aligning it with the unique requirements and objectives of the organization.

By addressing these objectives, the study endeavours to provide the organization with a practical roadmap for creating an efficient and customized BIM library platform that enhances operational efficiency, data accessibility, and collaboration across projects.

To achieve this, a mixed-method research methodology was formulated. This approach seamlessly integrates both qualitative and quantitative research methodologies to yield a comprehensive understanding of practices, challenges, and opportunities within the scope of BIM library management. Qualitative research methods – including interviews, document analysis, and observations, facilitate an in-depth exploration of the intricate aspects of BIM library management and its seamless integration into the organizational workflow. These qualitative methods provide valuable insights into the nuanced aspects of the subject matter. In contrast, quantitative research methods, exemplified by the administration of surveys and subsequent statistical analysis, are employed to systematically collect, and rigorously interpret structured data. This quantitative approach ensures that empirical evidence is gathered, allowing for the quantification of various variables, and enabling statistical comparisons and inferences. The combination of these research methods would ensure a holistic and well-rounded examination of the research topic.

Each chapter of this dissertation has been developed to respond to the systematic development of the research objectives as the table below shows

Table 1 – Chapter breakdown

Chapter 1	General introduction into the background of the study and a synopsis of the entire research
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Chapter 2	Contextual literature review to deepen the author's understanding of relating subjects
Chapter 3	Breakdown of research strategy, tools and procedures deployed
Chapter 4	Collection and analysis of data from various sources e.g., survey forms, document analysis, workflow mapping etc..
Chapter 5	Case study analysis of BIM Objects libraries in public domain
Chapter 6	Development of BIM Library management platform guidelines and its integration into organisational workflow
Chapter 7	Conclusion of the research, and recommendations for future possibilities.

This research is designed with a specific focus on the unique characteristics and requirements of the company under study. Nonetheless, the findings, analysis, and results obtained from this study possess a broader applicability and can be of significant value to similar organizations operating within the same domain.

The primary scope of this research is concentrated on delineating the prerequisites and guidelines essential for the establishment and administration of a BIM Library management platform. While this research may not encompass the entire technical development process, it plays an instrumental role by providing supplementary documentation that lays a solid foundation for the subsequent technical phases. In essence, while this study is tailored to the specific needs of the company in question, it has the potential to serve as a valuable reference point and source of insights for a broader range of organizations facing similar challenges and objectives within the realm of BIM Objects Library management platform.

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2. LITERATURE REVIEW

2.1. Background Of Study

The adoption of Building Information Modelling (BIM) has experienced a remarkable upswing in recent years. Institutions, researchers and authorities continually sought for ways to maximise this innovative trend. Understanding the evolution of its adoption can help predict the future needs of the AECO industry. (Elodie & Halin, 2018) describes BIM as an innovation hence subjecting it to the lexical field generally attributed to the spread of innovations – diffusion, adoption and implementation. This implies that as with other innovations however not explicitly, the following can explain each stage through different literatures;

Table 2 – Stages of Innovation (Elodie & Halin, 2018)

	“a concept that represents the spreads of the system/process within a population of adopters” (Mohamad & Bilal, 2017)
Diffusion	“The diffusion process is characterized by increases over time in both the number of firms using or owning a technology (inter-firm diffusion) and more intensive use of the technology by the firm (intra-firm diffusion).” (Stoneman & Diederer, 1994)
Implementation	“a set of activities undertaken to prepare for, deploy or improve specific deliverables and their related workflows” (Mohamad & Bilal, 2017)
Adoption	“Referred to as it sometimes refers to a company’s management decision to start integrating a technology; to the moment the technology is well mastered; or to a process that includes implementation” (Elodie & Halin, 2018)

Building on this context, the emergence of BIM has scaled towards the implementation and adoption phases depending on countries or organisations sampled. This characterization gave rise to the concept of BIM adoption levels. According to NBS (McPartland, Richard, 2017), “The concept of ‘BIM Levels’ (and ‘BIM Level 2 compliance’) has become the ‘accepted’ definition of what criteria are required to be deemed BIM-compliant. By seeing the adoption process as the next steps in a journey that has taken the industry from the drawing board to the computer and, ultimately, into the digital age”. The BIM level 2 compliance according to the Scottish Futures Trust, is distinguished by collaborative working, and requires "an information exchange process which is specific to that project and coordinated between various systems and project participants". This emphasises the information exchange process as the core of adopting BIM.

This research has been borne out of this level of adoption – the interest of an organisation to deepen its usage of a technological tool to improve information exchange. (Elodie & Halin, 2018) further the discussion by highlighting BIM adoption influencing factors stating that the innovation adoption is a

long and complex process, which implementation is a part of. Summarising these factors into 4 as shown the table below.

Table 3 – Summary of factors affecting adoption of innovation

Perceived BIM/Innovation Characteristics	A firm’s idea about the value of the innovation (Waarts, et al., 2002), perceived usefulness of the technology, ease of use (Davis, 1989), complexity level, compatibility, observability, and technological factors (Stoneman & Diederer, 1994;
Adopter characteristics	Company’s general attitude towards the type of innovation, and financial resources it devotes to Information Technology.
Internal environment characteristics	Top management support, organisational readiness, culture and size, financial resources, social motivation, communication behaviour and willingness/intention.
External environment characteristics	This includes normative pressures, market forces, mimetic pressures, coercive pressures, and supply chain integration

The implementation of solutions such as customised BIM libraries characterises a level of adoption induced by institutional change. It suggests from the table above, that for adoption to occur, the organisation has perceived the value of the innovation (Perceived characteristics), developed the needed attitude and finance towards that type of innovation (Adopter characteristics), backed by management support and intention (internal environment characteristics), and driven by normative pressures and market forces.

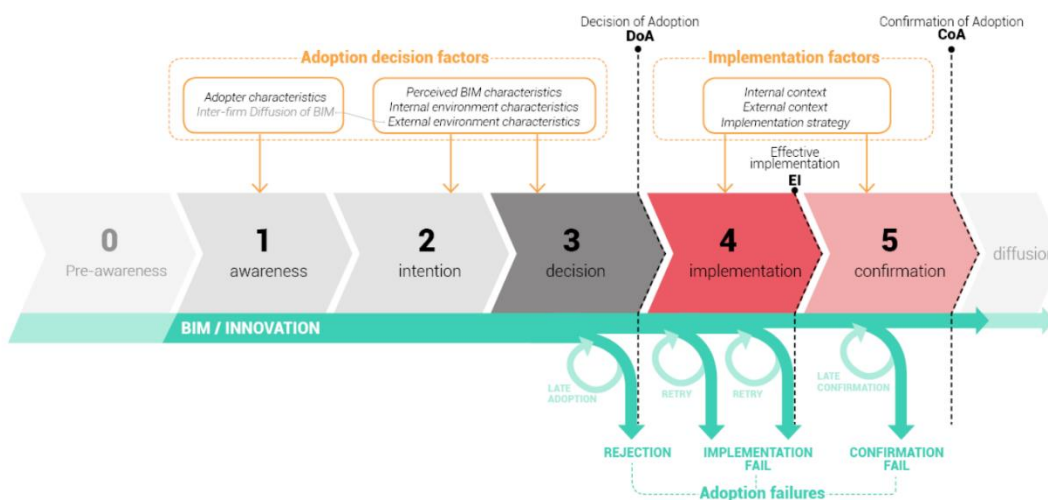


Figure 1 – Model of the BIM Adoption process, with possible adoption failures (Elodie & Halin, 2018)

In the analysis conducted by Elodie and Halin (2018) above, they examined innovation diffusion models and technology acceptance models within the context of BIM-specific literature. The objective was to formulate a model that elucidates the process of BIM adoption. In this model, particular emphasis was placed on the pivotal phase known as the "Decision of adoption," which emerges as a crucial juncture that precedes the actual implementation process..

At the organisational level where this research is carried out, the steps in effecting a change in a company can vary depending on the change management model or approach used. However, a commonly cited framework for change management is the ADKAR model, which stands for Awareness, Desire, Knowledge, Ability, and Reinforcement.

1. **Awareness:** This step involves creating awareness among employees about the need for change. It includes communicating the reasons for change, the benefits it will bring, and the consequences of not changing.
2. **Desire:** In this step, the focus is on creating a desire or motivation for change. It involves addressing any resistance or concerns that employees may have and highlighting the positive outcomes that can be achieved through the change.
3. **Knowledge:** The knowledge step involves providing employees with the necessary information and training to understand and implement the change. This includes educating employees about the new processes, systems, or technologies that will be introduced.
4. **Ability:** Once employees have the knowledge, they need to develop the ability to implement the change effectively. This step may involve providing additional training, coaching, or support to ensure that employees have the skills and resources required to carry out their new roles or tasks.
5. **Reinforcement:** The final step is reinforcement, which involves sustaining the change and ensuring its long-term success. This can be done through ongoing communication, monitoring progress, providing feedback, and recognizing and rewarding employees for their efforts.

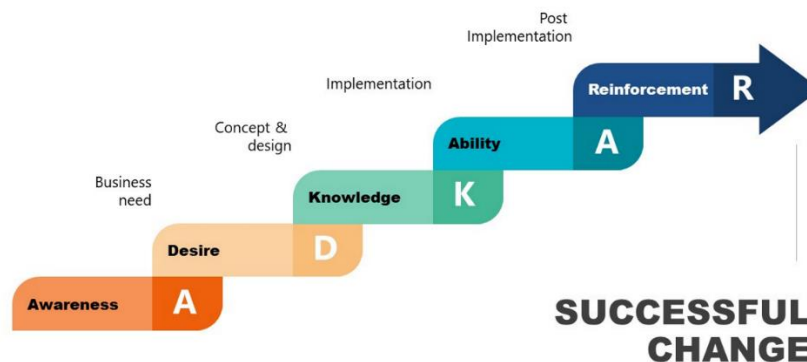


Figure 2 – ADKAR Model

It is important to note that this is just one model of change management, and there are other frameworks and approaches that may have different steps or variations. The specific steps and their implementation may also vary depending on the nature and scope of the change being implemented in the company (Prosci, n.d.). In the context of organizational change management, particularly within the realm of BIM adoption, understanding the dynamics between BIM objects, BIM models, and the BIM library is pivotal. It underscores the importance of not only having access to a comprehensive set of BIM objects but also ensuring that they are effectively managed and integrated into the BIM models. This understanding serves as the foundation for recognizing the need for a dedicated BIM library management platform.

The introduction of such a platform aligns with the principles of change management, particularly the ADKAR model. It bridges the gap between the "Desire" and the "Knowledge" phases within the model. By comprehensively examining existing workflows, addressing resistance factors, and presenting concepts and designs that can be implemented, this research is designed to stimulate and cultivate a desire for optimization and fostering collaboration among stakeholders involved in the BIM process within the target organization. It recognizes the transformative potential of a well-structured BIM library management platform and its role in enhancing the adoption and effective utilization of BIM within the AECO industry

2.2. BIM Objects

BIM objects contain detailed information about these components, such as their geometry, materials, dimensions, performance characteristics, and other relevant data. They are a fundamental part of the BIM process, which aims to create a collaborative and data-rich digital model of a building or infrastructure project. The BIM objects are created by manufacturers and designers, who use the data within them to ensure that the physical components they are creating meet all the requirements for a given project. Architects, engineers, and constructors can then use this data throughout the design process to make sure that everything is up to code and will be completed correctly. The BIM objects also provide an ongoing record of the project's progress, allowing all stakeholders to stay updated on its status. This helps to ensure that projects are completed on time and within budget. Additionally, BIM objects can be used after construction as part of a facility's maintenance and operations plan. BIM objects include a vast database of data that includes, among other essential details, attributes like mass, materials, carbon monoxide content, producer, composition, hue, spatial prerequisites, intricate technical specifications, surface texture, warranties, certifications, and informational documents. etc

These parameters can be customised based on the requirements and BIM object use. BIM objects operate in the built environment much like the actual product or element would. This entails testing various alternatives and practically mimicking how a product will work. Since the BIM model contains information about every construction component, you can see where different elements interact with or clash with one another. This might be particularly significant if the BIM model undergoes major changes or other iterative processes.

BIM objects often come from the product maker as they have up-to-date, accurate, and reliable product information, making them the best job choice. Since BIM objects store visual and functional product data and simulate actual product performance, these items are priceless resources for manufacturers

because they streamline brand awareness and put products squarely in the purview of BIM modellers, architects, and designers. Manufacturers can create BIM items themselves or outsource the modelling task to a third party. The conception of BIM objects as intelligent, standardised, and interoperable entities that adhere to the most recent international standards is of the utmost significance. This guarantees them compatibility with a wide range of applications and systems. All manufacturers stand to gain from deploying a vital Product Information Management (PIM) system, regardless of whether they choose to create BIM objects internally or externalise their modelling efforts (Eurovent Certita Certification, 2022).

A BIM object is an aggregation of many different components and by including visualization data, the item gains a recognizable visual resemblance. In addition, incorporating behavioural data, such as detection zones, enables the item to be positioned or to mimic the product's behaviour in the actual world accurately.

There are two (2) primary types of objects that make up the taxonomy of BIM objects, namely “component” and “layered”.

- i. The **component objects** encapsulate building elements characterised by fixed geometric configurations, encompassing entities like windows, doors, and boilers.
- ii. The **layered objects** are building products with no fixed shape or size, such as carpets, finishes, membranes, roofing, walls, flooring, and ceilings.

Other ways to classify objects could be “generic” or “specific”.

- i. **Generic objects**, frequently referred to as library objects, serve as provisional stand-ins known as “placeholders” during the preliminary design stage to visually articulate the necessity for a specific object to be designated in subsequent phases.
- ii. **Specific Objects**, on the other hand, are commonly termed manufacturer objects. They embody entities that accurately depict the unique products offered by a particular manufacturer. In the case of this research, they also include customised or created objects by designers or modellers with no specific manufacturer. e.g., concrete walls, slabs, etc.

Building components with set geometric arrangements, including windows, doors, and boilers, are encapsulated inside components. On the other hand, layered items refer to architectural materials lacking fixed dimensions or forms, including carpets, roofing shingles, walls, and ceilings.

2.3. BIM Models

BIM models, however, originate from individual constituents termed BIM objects. These digital entities represent virtual renditions of products and materials, commonly portrayed in three-dimensional form, encapsulating the object's geometry and intrinsic attributes. Within BIM objects, an extensive array of information is encompassed, encompassing parameters like mass, originator, composition, hue, texture, carbon monoxide content, technical intricacies, spatial prerequisites, informational documents, accreditations, and guarantees. Significantly, BIM objects emulate the comportment of tangible products

within the constructed milieu. Consequently, they facilitate the emulation of product performance and the virtual exploration of diverse alternatives, all cost-efficient and efficacious. Due to the comprehensive integration of all construction facets within the BIM model, identifying clashes or interferences amid objects becomes viable. This assumes particular significance in scenarios where modifications are introduced to elements within the BIM model. (Eurovent Certita Certification, 2022).

2.4. BIM Library

The Italian standard UNI 11337-1 defines the BIM objects library as a digital environment for gathering and sharing graphic and alphanumeric model objects. Within the realm of Building Information Modelling (BIM), a repository comprising semantically rich BIM objects stands out as an essential cornerstone in BIM-facilitated design and information management. Remarkably, the absence of such an exhaustive assortment of objects accessible to everyday BIM users serves as one of the primary factors accounting for the lukewarm adoption of BIM practices (Weisheng, et al., 2017). BIM libraries are digital databases or repositories that contain parametric BIM objects. These objects are the major components of buildings, such as doors, walls, beams, and MEP ducts or pipes. BIM libraries provide users with access to a collection of semantically rich and standardized BIM objects that can be used in BIM software for design, construction, and project management purposes. While some of these libraries are typically developed by open access sources, some others are tailored for a particular file format. They are integrated into a well-defined structure, allowing users to easily search, select, and download the objects they need for their projects (Weisheng, et al., 2017)

3. RESEARCH METHODOLOGY

This chapter describes the study's research methodology, including the strategies, tools, and procedures used for data collection, analysis, and interpretation. It emphasises the significance of methodological rigour in ensuring research findings' validity and reliability. In the context of this research, it is important to note that all activities carried out are subjected to the organisation under study while other parts are objective.

3.1. Research Framework

3.1.1. Research Approach

This study uses a comprehensive mixed-methods approach to gain a deeper understanding of BIM library management and corresponding user workflow in the context of diverse teams on a large-scale design. Recognising the multifaceted nature of BIM library management, the varying competencies of users and existing organisational workflow, this approach employs both qualitative and quantitative research methods to provide a comprehensive picture of practices, challenges, and opportunities. Qualitative methods, such as interviews, document analysis, and observations, enable a thorough examination of the complexities of BIM library management and its integration. These techniques expose the underlying processes, user behaviours, and large teams' interaction while executing BIM processes on complex projects. Quantitative methods, on the other hand, such as surveys conducted and statistical analysis, allow for the collection and interpretation of structured data. Surveys reveal broad library usage patterns, user preferences, and quantitative measures of library effectiveness.

3.1.2. Research Strategy

A strategic case study methodology is used in this research endeavour to shed light on real-world practices and extract insights tailored to the specific contextual landscape. The research includes an examination of four distinct BIM Libraries, which have been meticulously documented to allow for a thorough analysis. This case study approach is the illuminating lens through which the differences and similarities between various BIM library platforms are examined. It entails scrutinising a typical user's interactions within the library's various segments and comparing them to a predefined set of comprehensive parameters. These standardised parameters transcend online libraries and serve as the foundation for customised organisational BIM libraries.

To ensure contextual relevance and focus, the architectural discipline within the research organisation's Buildings Department was strategically chosen for an in-depth investigation. The research strategy is multifaceted, including an examination of the current workflows inherent in the architectural discipline. This entails examining BIM objects, storage protocols, and retrieval procedures. The analysis is carried out firsthand, involving an in-depth examination of an ongoing project, its actors, the BIM procedures used, and the overarching dynamics governing the project's progression. The results of this current workflow analysis have been meticulously crafted into a process map using the Business Process Model and Notation (BPMN). These visual representations shed light on the complex interactions that exist between all stakeholders associated with the sample department within the research organisation. This

encompasses their pivotal roles in BIM object management and their broader involvement in the overarching BIM processes. These investigative strategies are supplemented by a variety of data-collection techniques. Structured surveys, casual but insightful interviews, formal and informal discussions constitute this data. These interactions not only supplement the data gathered through observational methods, but they also provide a multifaceted view of the research landscape. Furthermore, the collaborative dynamics among teams, the nuanced characteristics of individual projects, the underlying organisational structure, and other pertinent considerations elucidated by the research organisation's management echelons collectively enrich the research insights.

3.2. Data Collection and Analysis

3.2.1. Surveys

Online survey forms created using the Microsoft forms are administered to stakeholders, including BIM coordinators, designers, engineers, and management staff. The survey collects data on library usage patterns, user preferences, and challenges faced. Responses are to be analysed and deductions used in the subsequent development.

3.2.2. Interviews

Casual interviews are conducted with key personnel involved in BIM library management. These interviews provide in-depth insights into existing library practices, workflows, challenges and other organisational goals in that respect.

3.2.3. Document Analysis

Existing documents such as BIM development templates, library catalogues, workflow diagrams, and historical records are analysed. This analysis reveals the historical evolution of library management practices.

3.2.4. On-Site Observations

On-site observational experience on how BIM library tools and workflows are used in daily practice of an ongoing project is made. These observations help validate data obtained through other methods creating deeper understanding for development of final output.

3.2.5. Case Studies

Popular BIM libraries within the public domain is to be analysed based on a set of parameters to understand the underlying intricacies of creating a BIM library. These parameters cut across the different layers of the library from user facing features to backend functionalities.

3.3. Limitations of the study

This study acknowledges potential limitations such as unavailability of useful official documents, willingness of stakeholders to participate, and possibility of response bias in surveys.

This chapter concludes by emphasizing the appropriateness of the research methodology for achieving the research objectives. It underscores the significance of robust methodology in producing meaningful and actionable research findings. By following this comprehensive research methodology, the study aims to provide valuable insights informing the design of a BIM library management platform.

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4. DATA COLLECTION AND ANALYSIS OF CURRENT WORKFLOW

This chapter discusses the mode of assessment, data collection and analysis of the current workflow in the client company in the pursuit of optimising the BIM library management. It delves into the intricate details of the existing workflow. A comprehensive understanding of the present workflow is pivotal for laying the foundation for practical improvements. This chapter encapsulates the methodologies employed to gather data, an analysis of the collected information, and an insightful examination of the current BIM level of adoption.

The data collection process was robust and multi-faceted yet interactive, involving a semi-structured survey of stakeholders actively and passively engaged with the BIM library and a casual conversation with other stakeholders in the company who had previously studied this subject. Their perspectives provide invaluable insights into the practical nuances of the existing workflow, the possibilities of an improved workflow and the design of a BIM library platform. Additionally, a crucial meeting with the BIM coordinator and the discipline leader further enriched the dataset with strategic viewpoints. These collaborative initiatives elucidate the intricate nuances embedded within the prevailing workflow, thus paving the way for an expedition marked by substantial transformative prospects.



Figure 3 - Image showing disciplines in the department of study

The Buildings Department of the research company, as shown in Figure 3 above, is a conglomerate of 3 major disciplines with multiple sub-disciplines. With the significant disciplines of Architectural (ARC), Mechanical and Plumbing (M&P) and Electrical and Instrumentation (E&I). The sub-disciplines for ARC are Architectural (BB) and Building Equipment (BQ), M&P – Plumbing system (BU) and Heating, Ventilation, Air conditioning (BH), for E&I – Electrical system (BN), Telecom systems (BT), fire and gas (BK) and Automation and Control Systems (BJ).

Building design coordination has been performed since the beginning of the design workflow through an integrated building 3D Model developed with the BIM approach. Due to the interrelation between

the Buildings Department and the Civil/Structural Department, projects are earmarked according to departmental competencies for best performance and delivery measures. For all building types, architectural and HVAC design is performed by the Buildings Department; regarding civil design, the battery limit between Buildings and Civil & Structural is anticipated as follows:

Design by Civil & Structural

- Foundation
- Structural frame in elevation in reinforced concrete or steel
- Concrete floor slab, trenches, concrete walls, concrete ladders
- Reinforced concrete paving on grade
- Gratings, chequered plates, handrails, steel ladders and stairs

Design by Buildings Department - Architectural

- Masonry walls in concrete or other materials like gypsum board
- Screed and mortar layers for sloping and protection layers
- Plaster layers
- Building architectural finishing
- Building Equipment and Furniture

Regarding design data exchange between engineering disciplines, the Building Design Project Leader (BDPL) is the focal point for all the coordination activities between engineering disciplines and the Buildings Department.

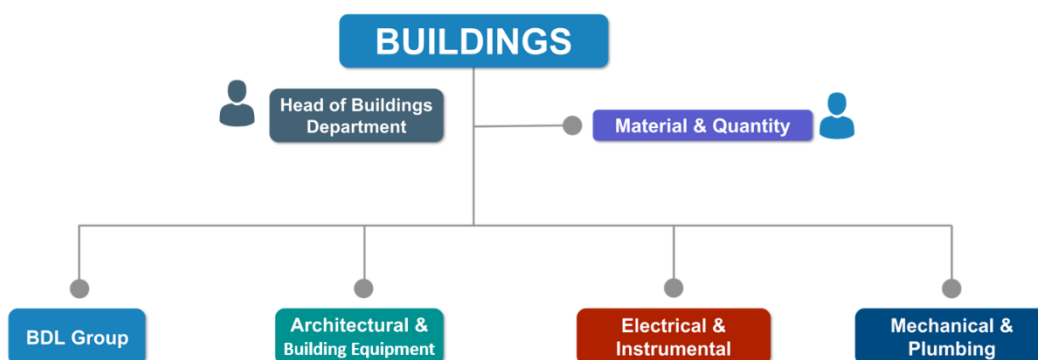


Figure 4 – Buildings Department Organogram

Figure 4 above shows the disciplines within the Buildings Department which potentially interact with a typical BIM project. This distribution of fields increases the tendency of function-based responsibilities,

which is where the BIM coordinators fill in. Buildings Department BIM Coordinator coordinates the development of the integrated design of buildings across each discipline, approving BIM models created by BIM modellers, BIM object (Revit families) creation, metadata parameters, level of development (LOD), and managing CDE and other BEP requirements.

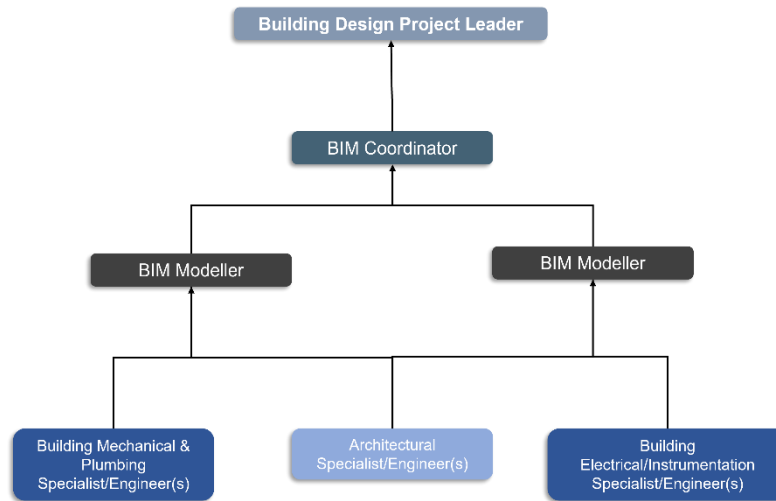


Figure 5 – Buildings Department BIM modelling tree

The chapter unfolds through distinct subheadings, each shedding light on various aspects of the current workflow.

4.1. AS-IS Process Map

The chapter's methodology to understand and assess the client organisation's workflow commences with a visual representation of the AS-IS process map, meticulously laid out as a Swimlane map. Generally, process mapping allows you to solidify ideas and streamline processes by visually communicating the steps needed to execute an idea. This map serves as a guidepost, illuminating the journey undertaken by the client's organisation in its current state. The simplicity of the graphical and visual models can also assist in the brain's cognitive functions. The technique selection to be employed depends on the intended purpose of the modelling and the specific elements to be captured and conveyed. At its fundamental essence, a process representation typically encompasses an input, an output, and a series of activities orchestrated to fulfil the process's overarching objective. (Johansson & Nafsi, 2020).

This process map is essential in this methodology for several reasons:

- i. **Visibility and Clarity:** The AS-IS process map provides a clear insight into the execution of tasks, the utilisation of resources, and the flow of information to, through and from the BIM library under study. This clarity is essential for recognising points of congestion, inefficiencies, and duplications.
- ii. **Identification of Gaps and Inefficiencies:** The map aids in identifying gaps and redundancies within the workflow, thereby pinpointing areas that require optimisation. These insights

(M&P) Electrical and Instrumentation discipline (E&I). Due to the intersecting nature of different fields within the department interfacing with various departments within and outside the company, there is an enormous crossflow of data in several mediums. With the integrity of this data constituting a significant part in the success of any BIM project, especially large-scale projects like industrial plants, which is the client’s domain, BIM models sit in the core of this exchange.

According to (Borrmann et al., 2015), In projects that engage numerous contributors across diverse organisations, the primary emphasis frequently shifts away from the comprehensive, all-encompassing process to concentrate on individual tasks within the framework of each participant's distinct sphere of accountability. This organisational structure based on functions can impede effective communication among various entities, often resulting in insufficient resolution of matters spanning multiple domains. This function-based approach limits the possibilities of the BIM process by taking the emphasis away from the holistic view of the project, allowing for gaps due to inefficiencies when some responsibilities fall between two distinct functions or, in this context, disciplines—further explained, the most significant challenges in adapting processes arise from the need to surmount the conventional hierarchical organisational structures that dominate project management within the construction industry, often oriented towards specific functions.

These gaps, in the long run, could result in loss of person-hours, omission of vital elements or worse, compromising the integrity of BIM data for future use.

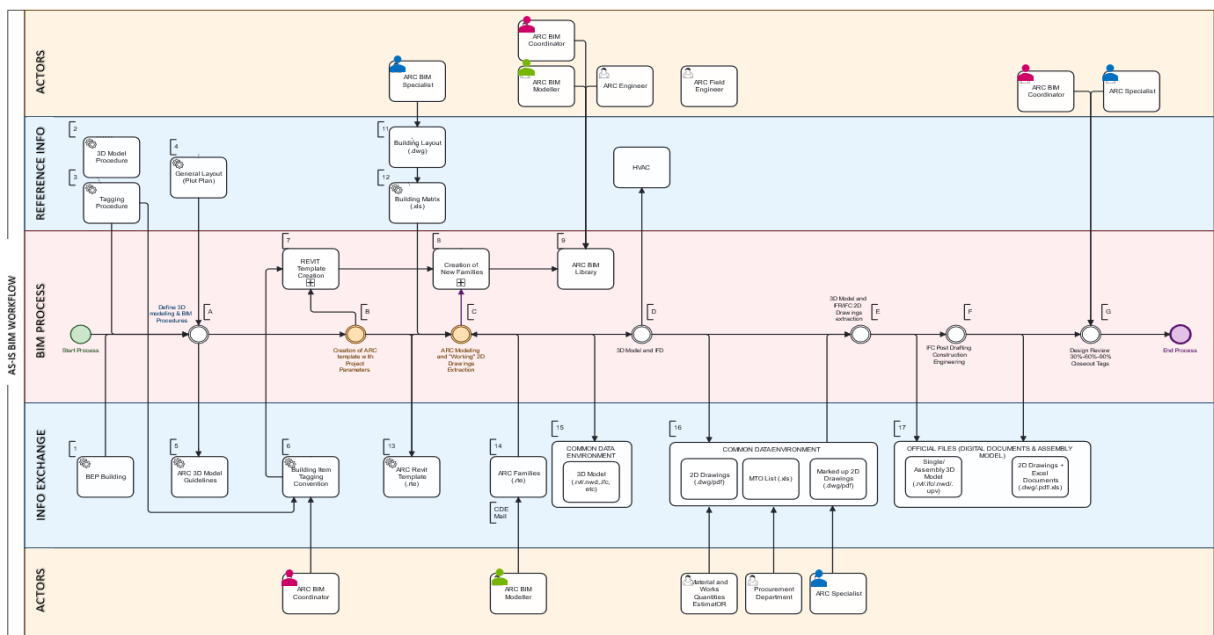


Figure 7 – Architectural Discipline AS-IS Process Map

The flow of information in and out through the BIM process and how it connects to the BIM library is analysed. Figure 7 above shows the process flow through the Architectural discipline of the Building Department under study. This map contains three major swimlanes names. Tagged in the “BIM Process” swimlane alphabetically are the core milestones to completing a BIM Project in the department.

Once a project is awarded, a Building Design Project Leader is nominated by the Buildings Department. The BDPL, based on Project complexity and scope of work, is assigned a team of engineers and specialists typically:

- Architectural Specialist/Engineer(s)
- Building Mechanical & Plumbing systems Specialist/Engineer(s)
- Building Electrical /Instrumentation systems Specialist/Engineer(s)
- BIM coordinators

For each project, at least one Material Resources/Work Resources (MR/WR) specialist or engineer is designated to oversee materials and work quantity management. The Building Design Project Leader operates under the guidance of the Project Engineering Manager (PEM) and maintains collaboration with the Plant Design Manager and System Design Manager if they are appointed for the specific project. Furthermore, close communication is upheld with other Discipline Project Leaders to facilitate the continuous exchange of essential information necessary for project development. Upon the availability of requisite information, the Building Design Project Leader conducts an in-depth analysis and proposes an execution strategy for the building project. This strategy is subsequently subject to approval or revision by the PEM and PD/PM. The Building Project execution strategy lays the foundational framework upon which all other disciplines build their respective processes. Within the Buildings Department, the Building Execution Plan (BEP), 3D Model Procedure, tagging procedure, and general layout (plot plan) collectively serve as the primary inputs that inaugurate the commencement of the BIM (Building Information Modelling) process, as elucidated in Table 4, showcasing the information flow across the BIM ARC process.

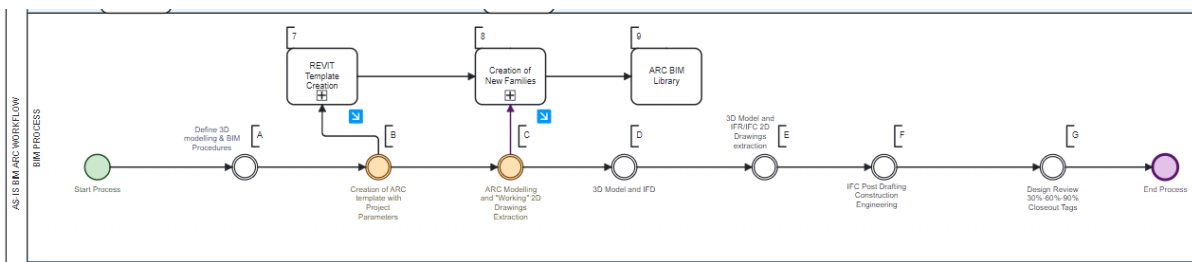
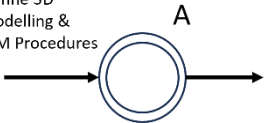
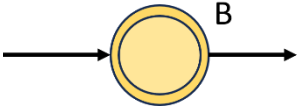
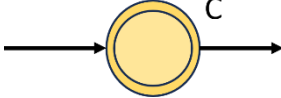
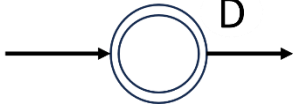
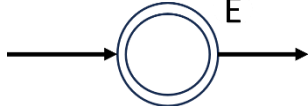


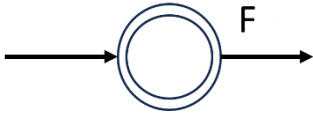
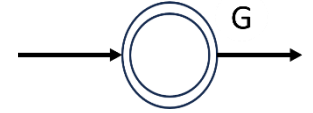
Figure 8 – Primary Architectural BIM Process

This reference information plays a pivotal role in defining the procedures for 3D modelling and BIM implementation specific to the project. The initial stage, denoted as "A" on the process map, yields the "ARC 3D Model Guidelines." This document delineates the precise procedures governing the project's 3D modelling processes. Subsequently, in process "B," the ARC template with project parameters is generated using this document, constituting a critical step in the workflow. The outcome of this stage is the project-specific ARC Revit template in ". rvt" format, which is made accessible to all involved contractors and modellers through the Common Data Environment (CDE). Notably, during this stage, primary BIM objects, such as Revit families tailored to the project's requirements, are pre-loaded into

the ".rvt" template from the pre-existing BIM objects database. A comprehensive elucidation of this BIM process is provided in subsequent sections of this chapter.

Table 4 – Information flow across the primary ARC BIM process.

S/N	Input (Reference Info)	BIM Process swimlane	Output (Info Exchange)
A	BEP Building	Define 3D modelling & BIM Procedures 	3D Model Guidelines
	3D Model Procedure		
	Tagging Procedure		
	General Layout (Plot Plan)		
B	Building Item Tagging Convention	Creation of ARC template with Project Parameters 	ARC Revit Template
	ARC 3D Model Guidelines		ARC BIM Library
C	ARC Revit Template	ARC Modelling and "Working" 2D Drawings Extraction 	3D Model (.rvt/.nwd,.ifc, etc) via CDE
	Building Layout (.dwg)		Creation of New Families
	Building Matrix (.xls)		
	ARC Families (.rte)		
D	3D Model	3D Model and IFR/IFC 2D Drawings extraction 	2D Drawings (dwg/pdf)
			MTO List (.xls)
			3D Model for HVAC
E	Marked up 2D Drawings (.dwg/pdf)	3D Model and IFD 	Single/ Assembly 3D Model (.rvt/.ifc/.nwd/.upv)
	3D BIM Model		*Official Submission
			2D Drawings + Excel Documents (.dwg/.pdf/.xls)

F	IFR/IFC 3D Model	<p>IFC Post Drafting Construction Engineering</p> 	<p>Single/ Assembly 3D Model (.rvt/.ifc/.nwd/.upv)</p> <p>*Official Submission</p>
			<p>2D Drawings + Excel Documents (.dwg/.pdf/.xls)</p>
G	IFR/IFC 3D Model	<p>Design Review 30%-60%-90% Closeout Tags</p> 	<p>Design Review and Close-out tags</p>

The Revit template (.rvt), building layout, and building matrix, developed by architectural specialists, alongside the BIM objects (.rfa) created by the BIM modeller/Coordinator, are employed as inputs for the process designated as "C," which constitutes the principal phase for modelling and generating 2D drawings. This phase stands as the cornerstone of the BIM modeller and Coordinators' work, as it encompasses the development of all designs proposed by the specialists. If deemed necessary, new BIM objects are also generated by the architectural specialist's specifications. The subsequent process phase, denoted as "D," is designated for 3D Modelling and Issued for Design Development (IFD). During this phase, the model is initially made available for other disciplines, namely E&I (Electrical and Instrumentation) and M&P (Mechanical and Piping). Additionally, 2D drawings (.dwg, .pdf) and the Materials Take-off (MTO) list (.xls) are uploaded to the Common Data Environment (CDE), serving as inputs for other departments and specialists, including the Procurement department and Materials/Works specialists. All revisions and annotations by the architectural specialist are performed on these IFD models and subsequently uploaded to the CDE as marked-up 2D drawings. The marked-up 2D drawings from the architectural specialist and other review inputs are iteratively incorporated into the model. This process fuels the subsequent phase, marked as "E," which encompasses 3D Modelling and IFR/IFC 2D Drawings extraction. At this juncture, the initial official submissions for the client are made accessible via the information CDE (Sharepoint) in a consolidated assembly of the 3D model, provided in formats such as .rvt, .ifc, .nwd, and .upv. This stage also entails comprehensive clash detection procedures since all other disciplines have already integrated their models.

The penultimate phase in the overarching workflow is designated as "F" - IFC Post Drafting Construction Engineering. During this phase, the final stages of 3D modelling are executed, followed by the inclusion of 2D drawings and all accompanying Excel documents, all of which are subsequently uploaded into the CDE to initiate the actual construction phase. The final phase within the design process is the "Design Review and Closeout" phase, denoted as "G." This stage encompasses the ultimate review and clash detection processes, alongside the introduction of close-out tags. It signifies the conclusion of the BIM design phase. It is pertinent to note that this research primarily focuses on the BIM library, thus the workflow analysis is limited to its relevance within the design phase where the BIM library predominantly finds its application.

Due to the expansive organizational structure of the client company, this AS-IS process map has been streamlined to specifically encompass interactions within the Architectural discipline of the Buildings Department. While this mapping serves as a pilot study, it resembles the workflows within other disciplines within the department, albeit with minor distinctions.

4.2. AS-IS BIM Object Database and User Workflow

The BIM Object database is the digital repository of the department that houses a curated collection of standardised BIM objects, components, and resources. These objects encompass various elements used in construction and design, such as walls, doors, windows, HVAC systems, and more. Each entity within the library contains comprehensive data, including geometry, material properties, functional characteristics, and performance data. As it stands, each discipline in the client buildings department has its BIM library, including the Architectural discipline, which is the leading study case of this research.

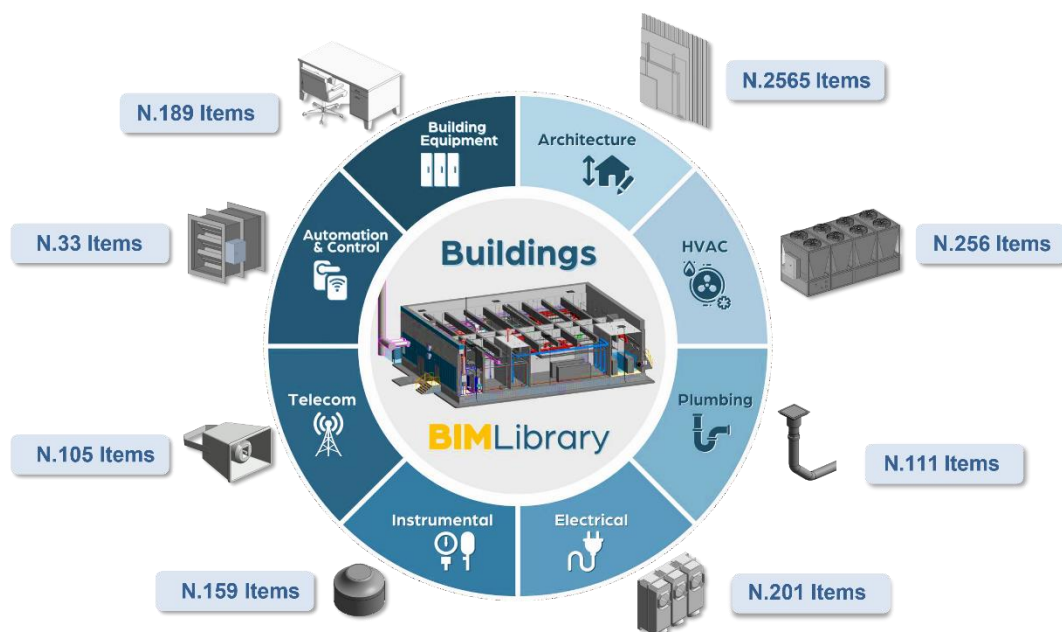


Figure 9 – Buildings Department BIM Objects database distribution

The BIM Object database and user workflow stand at the core of this research thereby causing a dive into the interaction of different actors with the objects storage system. Autodesk Revit is the primary authoring tool of the department, with other Autodesk services like BIM 360 serving as the Common Data Environment. The Architectural BIM library is composed of 1956 wall BIM objects, 52 for roofs, 41 for floors, 33 for ceilings, 87 for doors, 42 for windows and 354 other components. These numbers keep rising as projects are reviewed or new projects kick-off thereby creating a continuous process of creation, modification, and retrieval of BIM objects from the BIM library.

4.3. Revit Template

Revit templates are pre-configured project files in Autodesk Revit that serve as starting points for new design and construction projects. These templates include predefined settings, standards, and views,

helping streamline the initial project setup process. Only the specified BIM objects by the Architectural Specialist are included in the Revit template to reduce the potential size of a new project. Families are pre-loaded into the templates by the BIM coordinator before sharing with all the stakeholders for development. This phase is quite important as project file standardisation begins here before it is shared across all the modellers in and out of the company. General project information, project information on the landing page, project browser structure, legends, view properties, coordinates and other project set-up details are made on this template before sharing. By leveraging these templates, the company can ensure consistency in project documentation, adhere to company or industry standards, and accelerate the project's early stages, saving time and enhancing efficiency in the BIM workflow. In the existing workflow, after sharing this template with stakeholders, all BIM objects pre-loaded in this template cannot be automatically reviewed, modified, or managed due to the manual interaction between project files and the BIM library. This results in losing several man-hours in reviewing and editing BIM models for the affected BIM objects each time. Automation of this process is currently out of stock; however, depending on the technical competence of individual modellers, some employ automation, thereby giving rise to errors of inconsistencies like spelling errors in naming or tag codes or total omission of some objects due for review.

4.4. BIM Object Creation

BIM object creation is developing digital representations of building components or elements with detailed information that can be aggregated into a BIM model. A brief description of the BIM object creation is made to understand the development workflow leading to the current library collection. One of the most essential attributes of BIM object creation involves adherence to industry/company standards and guidelines to ensure compatibility and consistency across projects. Its character and avoidance of the repetitive need to create the same BIM objects gave rise to the current BIM library.

At the research company, a new BIM Object usually starts through a request by the Architectural specialist based on a project need. The BIM coordinator creates its new object type name and code using the existing naming protocol, after which the BIM modeller develops it using the company standards for modelling. In cases of review during an ongoing project, it is necessary to collect all newly created BIM objects for storage in the central BIM objects repository. However, this step is mainly omitted upon project completion. This emphasises the need for synchronisation features.

4.5. BIM Object Search Query and Use

All available BIM objects in the library across all the disciplines are contained in thousands of cells in rows and columns of data using Excel worksheets for each discipline within the department. This Excel file is used to sort, store, search and identify major data parameters contained by every BIM object available in the library.

OBJECT TYPE CODE	OBJECT JOB CODE	OBJECT TYPE CODE DESCRIPTION	Side A - layer 4	Side A - layer 3	Side A - layer 2	Side A - layer 1	Core Material	Side B - Layer 1	Side B - Layer 2	Side B - Layer 3	Side B - Layer 4	Side B - Layer 5
WB 70025	.0000	WET WALL (WALL CONSTRUCTION SYSTEM - HOLLOW CONCRETE BLOCK)					EXTERNAL PAINT 100mm THK. HOLLOW CONCRETE BLOCKS					INSULATION 100mm THK. HC INTERNAL PAINT
WB 70026	.0000	WET WALL (WALL CONSTRUCTION SYSTEM - HOLLOW CONCRETE BLOCK)					EXTERNAL PAINT 100mm THK. HOLLOW CONCRETE BLOCKS					INSULATION 100mm THK. HC INTERNAL PAINT
WB 70027	.0000	WET WALL (WALL CONSTRUCTION SYSTEM - HOLLOW CONCRETE BLOCK)					EXTERNAL PAINT 100mm THK. HOLLOW CONCRETE BLOCKS					INSULATION 100mm THK. HC CERAMIC TILES (ON MORTAR BED)
WB 70028	.0000	WET WALL (WALL CONSTRUCTION SYSTEM - HOLLOW CONCRETE BLOCK)					EXTERNAL PAINT 100mm THK. HOLLOW CONCRETE BLOCKS					INSULATION 100mm THK. HC ACID RESISTANT GRES TILES (ON MORTAR BED)
WB 70029	.0000	WET WALL (WALL CONSTRUCTION SYSTEM - HOLLOW CONCRETE BLOCK)					EXTERNAL PAINT 100mm THK. HOLLOW CONCRETE BLOCKS					INSULATION GYPSUM BOARD INTERNAL PAINT
WB 70030	.0000	WET WALL (WALL CONSTRUCTION SYSTEM - HOLLOW CONCRETE BLOCK)					INTERNAL PAINT 100mm THK. HOLLOW CONCRETE BLOCKS					INTERNAL PAINT
WB 70032	.0000	WET WALL (WALL CONSTRUCTION SYSTEM - HOLLOW CONCRETE BLOCK)					INTERNAL PAINT 100mm THK. HOLLOW CONCRETE BLOCKS					INTERNAL PLAS INTERNAL PAINT

Figure 12 – Filtering Search Query for the ARC BIM Library

The available headings to filter are object type code, object type code description, material layers (sides and core), system and sub-system description, type number, insulation, core material description, fire resistance yes/no, blast resistance yes/no. Identify its object type code.

- Within the Revit library, search for the object type code, and copy and paste it in the project of choice.

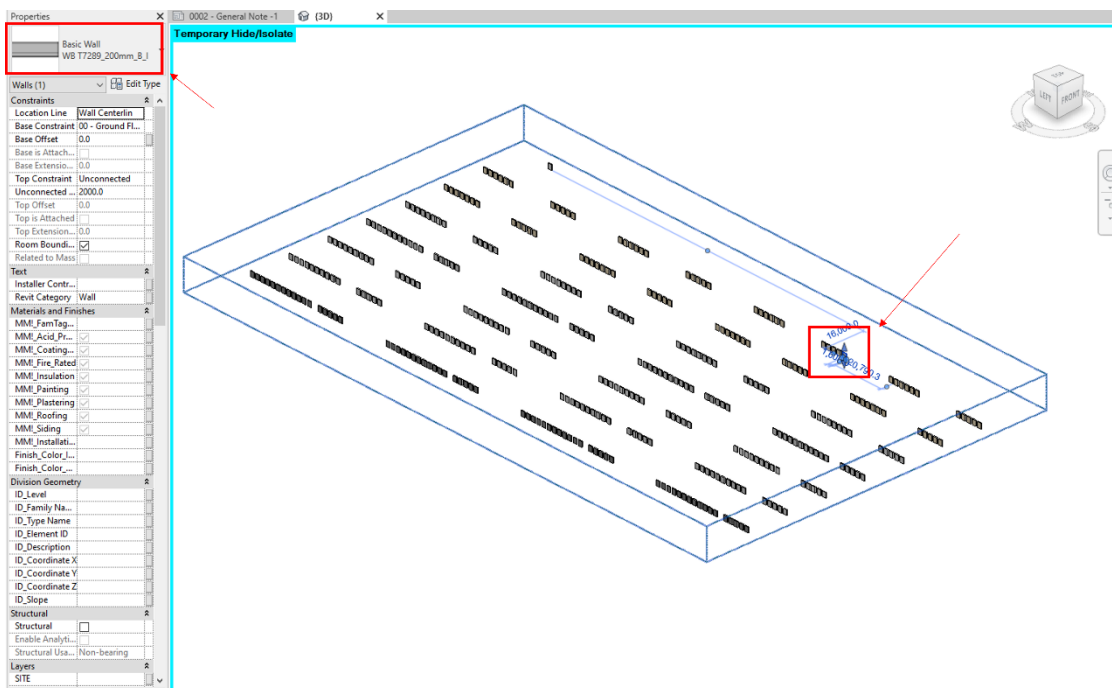


Figure 13 – Revit Project file for walls

In instances where the required BIM object, as stipulated by the architectural specialist, is not available in the library, the BIM modeller, with the endorsement of the BIM coordinator, undertakes the creation of a new family, adhering to established naming conventions. The data pertaining to the new BIM object is meticulously entered into the Excel database, following well-defined rules for updates. The complexity of this process amplifies when multiple BIM modellers, representing different companies, collaborate on the same project. As per the organisation's observations, this complexity engenders several challenges, including the duplication of BIM objects, a heightened risk of errors in naming conventions, and the proliferation of outdated information within the Excel sheets. These issues are primarily rooted in inconsistencies in the creation and update workflows.

Beyond the processes of BIM object creation, modification, and retrieval from the library, another pivotal aspect within the organisation pertains to the accessibility of this library by individuals who do not directly engage with the authoring software. These individuals encompass a broad spectrum of roles, including but not limited to the Building Design Project Leader, architectural and field engineers,

contractors, members of the procurement department, personnel responsible for accounting, materials and works management, and vendors. These actors collectively form an interconnected chain of responsibilities that align with project objectives. Consequently, they must gain access to project-specific BIM object data, encompassing details such as the number of building items, unit prices, material specifications, component attributes, dimensions, ratings, and more, particularly during the design phase.

Both technical and non-technical users exhibit regular engagement with this BIM library, accessing a diverse array of data essential for their respective work processes. Currently, this access is predominantly facilitated during the process phase denoted as "3D model and IFD," labelled as "D," where the initial Materials Take-off (MTO) list is generated. Before this phase, requests for additional details regarding project items were routed through the BIM coordinator, or, if granted access to the Common Data Environment (CDE), users navigated through the project model in pursuit of the required information. This prevailing workflow poses inherent frictional challenges, impeding the seamless and effective collaboration essential for project success.

4.6. Active User Experience and Survey

Survey research is a valuable methodological approach for systematically gathering insights from a defined cohort by presenting them with targeted questions and then scrutinising the resulting responses. A structured user survey was methodically administered after a meticulous analysis of the AS-IS process map and the existing workflows within the sample department. This survey was distributed to various stakeholders involved in the BIM process; individuals intricately involved in managing the current BIM object repository within the architectural discipline. It is critical to emphasise that the architectural discipline serves as the focal point for the pilot study within the context of the Buildings Department's broad scope. The rationale for this strategic choice assumes that the implementation of the upcoming BIM library management platform will begin in the architectural domain before expanding to include other disciplines. A precise taxonomy has been meticulously formulated within this spectrum of stakeholders, based on the competencies and designated roles typical of a BIM project. The classification includes several pivotal personas, each with unique expertise and responsibilities critical to the smooth execution of a BIM project. These personas include Architectural Engineers, Architectural Specialists, BIM Modellers and Coordinators, Materials and Works Quantities Estimators, Engineers, a Senior Designer who also serves as a BIM Coordinator, and, most notably, the Department Head.

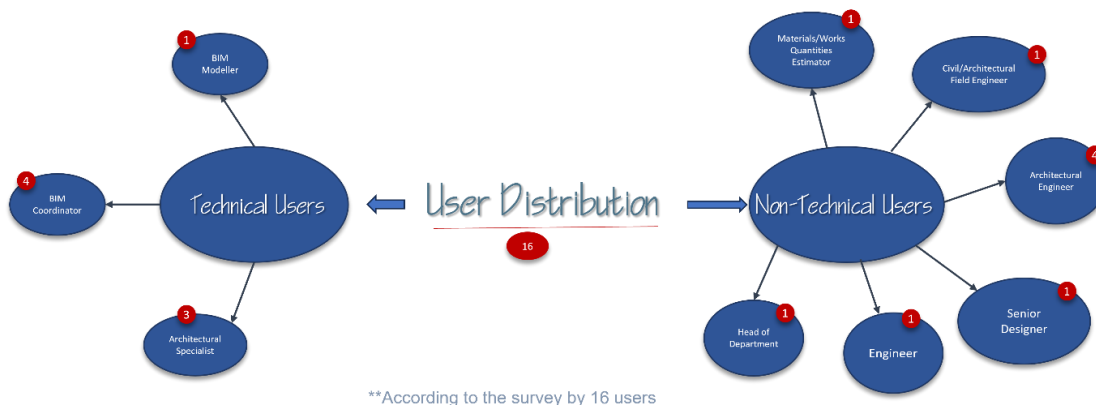


Figure 14 – Survey respondents distribution

4.6.1. Survey Feedback Analysis

The organisation's designated supervisor meticulously oversaw the survey administration process to ensure methodological precision and adherence to ethical standards. Robust measures were implemented to safeguard the confidentiality and sensitivity of the data furnished by the respondents. The survey questions were structured, particularly for inquiries concerning respondent preferences, interaction patterns, and various user metrics. Respondents were requested to rate their responses on a scale ranging from 1 to 10, signifying the spectrum from minimal to maximal significance respectively. Survey distribution was conducted exclusively within the organisational network, targeting a selected cohort of participants. The selection criteria were grounded in their professional designations and involvement within the architectural discipline, a subdomain of the department under investigation. This strategic approach was adopted to ensure respondents had firsthand experience and expertise in the BIM processes and object management practices specific to the architectural context.

4.6.2. Interaction with the current BIM Objects repository

This survey question delved into the diverse ways users interact with the existing BIM object repository. For a better understanding of respondents, the current BIM objects repository was termed a BIM library as that is the lingo commonly used within the organisation. Respondents provided insights into their engagement patterns, shedding light on how they utilise the repository for various purposes.

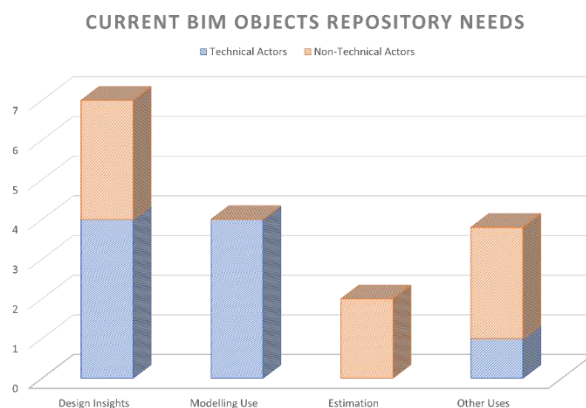


Figure 15 – Respondents BIM objects repository needs

The data analysis reveals that the primary motivation for users to access the existing BIM objects repository is to gain design insights, a preference expressed by 7 respondents. Additionally, 4 respondents cited modelling requirements as their key reason for utilizing the storage. Other noteworthy reasons include seeking a more profound comprehension of specifications, materials, and rendering aspects. This signifies that the envisioned BIM library management platform should prioritize user-friendliness, particularly facilitating seamless viewing and assessment.

The primary user requirements revolve around accessing design insights and fulfilling modelling needs, underscoring the need for intuitive and efficient design-centric functionalities. It is essential to add that users in managerial roles do not have an administrative window into the BIM repository despite highlighting “management of internal and external informational flow” as their main objective for visiting the BIM object database.

4.6.3. User Interface and Core Functionalities Analysis

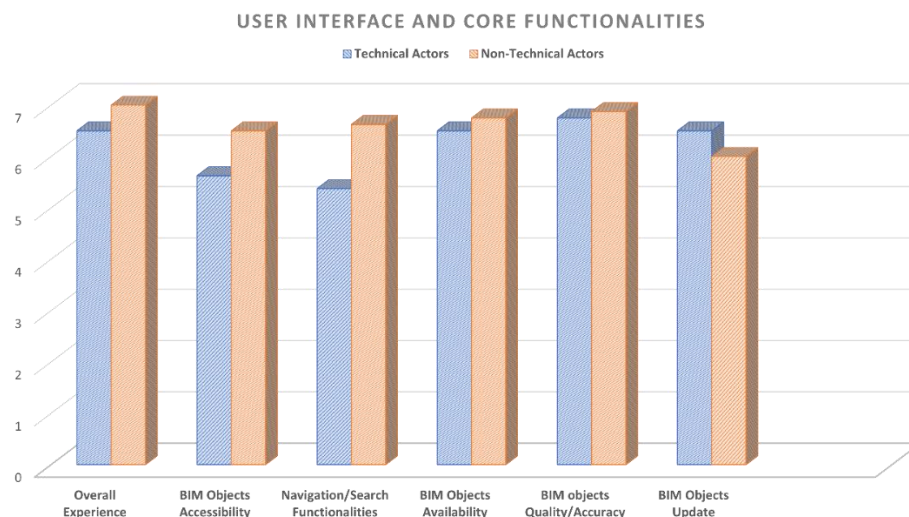


Figure 16 – Respondents' feedback – 1

The data suggests that the overall user experience receives a higher average rating from non-technical users compared to their technical counterparts. This disparity may be attributed to the support extended by technical users in addressing challenges encountered during usage. However, it is noteworthy that technical users face notable challenges in navigating and searching within the platform and accessing BIM objects. This observation aligns with the fact that all requests funnel through technical users for processing and clarification, intensifying their interaction with these pivotal functionalities and highlighting the imperative need for enhancements.

The analysis depicted in Figure 16 underscores a salient point: Technical users' ratings surpass those of their non-technical counterparts solely in the realm of BIM object updates. This discrepancy highlights a discernible gap between the efforts exerted by technical users and the experiences recounted by non-technical peers, shedding light on areas where targeted improvements may be warranted.

4.6.4. Retrieval, Collaboration and Support

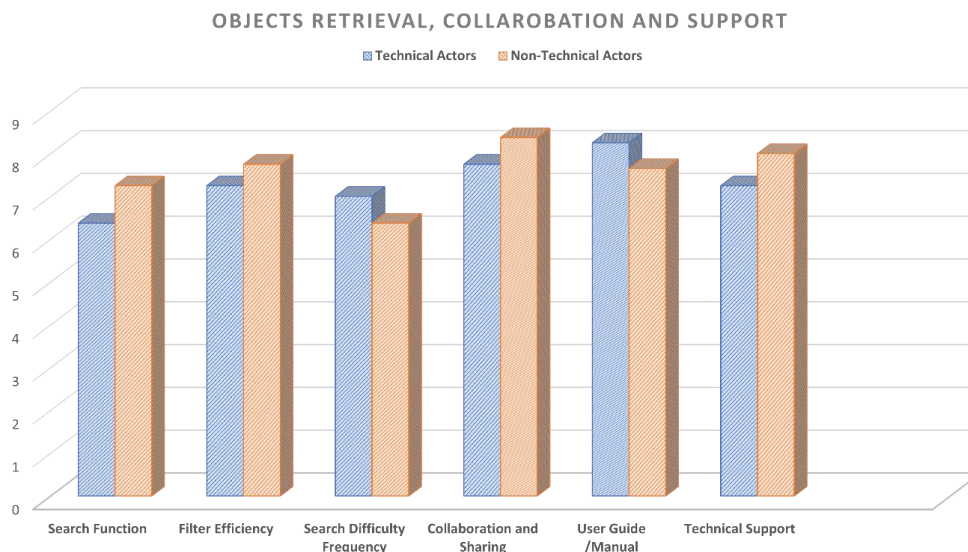


Figure 17 – Respondents’ feedback -2

From the feedback on retrieval, collaboration and support, technical actors have rated the search difficulty more than non-technical actors. This provides a critical insight as these are the custodians of the BIM objects creation, storage, and retrieval in the organisation. It points further into a need for a management platform that eases technical expectations democratising the accessibility to all stakeholders.

Other expectations recorded include:

- Accessibility without using licensed software or platforms
- Display image of BIM objects with parameters
- Availability of BIM objects should be based on project at hand
- Live update of BIM objects across projects
- Automated naming system within authoring software (Revit)
- Web-based platform like other BIM libraries
- Simpler user experience
- Direct extraction of dwg or other data formats
- BIM objects categorised by project type

4.7. SWOT Analysis of AS-IS BIM Objects Storage and Retrieval System

STRENGTH	WEAKNESS
1. Structured workflow with all stakeholders aware of responsibilities	1. Heavy reliance on technical users for clarity
2. Availability of technical professionals	2. Data Storage Complexity zoning out non-technical users
3. Detailed Data Parameters	

-
- | | |
|--|--|
| <ul style="list-style-type: none"> 4. Well documented tagging and naming convention 5. Technical Support for non-technical users | <ul style="list-style-type: none"> 3. Manual Processes of creation, review and management 4. Lack of Version Control |
|--|--|

OPPORTUNITIES

THREATS

-
- | | |
|--|--|
| <ul style="list-style-type: none"> 1. Implement Advanced Search Functionalities 2. User Training and Education 3. Streamlined BIM Object library 4. Development of a management platform | <ul style="list-style-type: none"> 1. Competitive landscape creates expectations for better workflows 2. User resistance to change 3. Technological advancement in BIM can render current workflow obsolete |
|--|--|
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5. CASE STUDIES

The skilful management of BIM libraries emerges as a pivotal determinant of streamlined operations, strengthened collaboration, and increased project deliverables in the field of industrial plant design and engineering. A thorough examination of existing platforms emerges as a requirement and an illuminating compass guiding our expedition in the search for a customised BIM library management solution.

In the scope of this academic research, an in-depth case study of four renowned BIM library platforms has been carried out. Each of these platforms—BIMobject, MagiCAD, RevitCity, and NBS BIM Library—has left a permanent mark on the digital landscape by providing architects, engineers, designers, and the large construction community with access to a repository of BIM objects, models, and other resources. These libraries will be referenced alongside each other as well as individual analysis. The meticulous inspection of these platforms, calibrated against a predetermined set of criteria, is at the heart of this investigative journey. These parameters, which have been carefully selected, capture the essential elements supporting the effective orchestration of a BIM library. The following are the significant parameters under which other sub-parameters are tucked:

- i. **User Interface:** Users interact with the library through a portal's user interface, which considers aspects like design layout and aesthetics, navigational intuitiveness, thumbnails and visual representation, object description, reconfigurability, and adaptive responsiveness. Its primary objective is to promote usability and accessibility.
- ii. **Core Functionality:** The strength of a BIM library's backend infrastructure determines how well it can be managed. File and metadata management, search and filtration algorithm, the frequency of content updates, data import/export, integration with BIM authoring software like Autodesk Revit and the platform's overall performance score are all essential components of this rubric.
- iii. **Collaboration and interaction:** In a collaborative environment, the ability of any digital resource to facilitate and improve user collaboration significantly impacts that resource's effectiveness. The parameters adopted in this context include mechanisms for soliciting and incorporating feedback, distribution channels for content, and the imposition of version control restrictions.

Listing these discerning criteria highlights both the pertinence of their comprehensive consideration and their integral relevance. When viewed separately, each parameter represents a pivotal axis around which a BIM library's usefulness and effectiveness revolve. The main goal of this investigation is to compare these benchmarks across the range of existing BIM library platforms, charting their unique profiles and stratified competencies.

5.1. BIMObjects:

BIMobject is a content management system hosted in the cloud specifically for Building Information Modelling (BIM) objects. It offers various modules to simplify BIM objects' online creation, conversion, and distribution. BIMobject has a tonne of features and resources. The BIMobject Corporation is

supported by a global network of businesses and partners. It creates digital replica 2D/3D libraries of real-world building products and interior components and is a conduit between manufacturers and BIM. It can create BIM objects for all the different BIM programs on the market, including Revit, ArchiCAD, SketchUp, and AutoCAD. It is vendor neutral. EAN codes, U-values, sizes, branding (logo), and family names are among the components. Links to assembly and maintenance manuals are also included. (Corke, 2014). Customers are automatically informed if specific products have been updated or removed and downloads are tracked so manufacturers can get a sense of the pipeline. With a strong reporting architecture, the business offers market analysis, business development, and lead generation. BIMobjects® provides BIM objects as virtual prototypes of fundamental building components developed in proprietary and open file formats.

5.1.1. User Interface

The user interface of BIMobject is user-centric as it is adapted to each user through preferences as labelled “3” in Figure 18 - BIMobject User Interface, with a top-bottom approach starting from search boxes marked “2” using keyword system to categories labelled “4” which is a form of filter, and suggestions through the headings brands, trending products and new products as labelled “5” in the figure below. It sets itself apart with a visually appealing and incredibly intuitive design. Users can easily navigate through the platform's extensive library, set their preferences, and, most importantly, notice how responsive it is across a wide range of devices. According to [comparecamp](#) a SaaS software comparison website, its ease of use was scored 9.5/10.

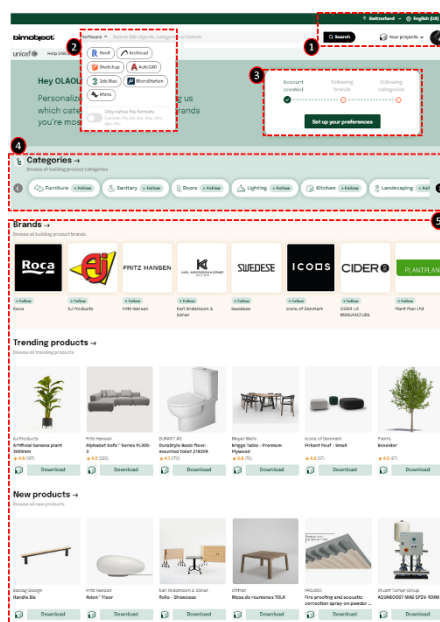


Figure 18 - BIMobject User Interface

The home page is furnished with everyday BIM objects suggestions under different headings that can pique the users' interests, making it easy to acclimate new users to how the platform works. When an object is selected, larger images of the thing are displayed with its properties on the sides, its official name, model, and type of object based on its category, size, and other descriptions. Most objects have

these headings – specification, technical specification, links, classification and related which contain additional information as highlighted in label “5” in Figure 19- BIMObject User Interface.

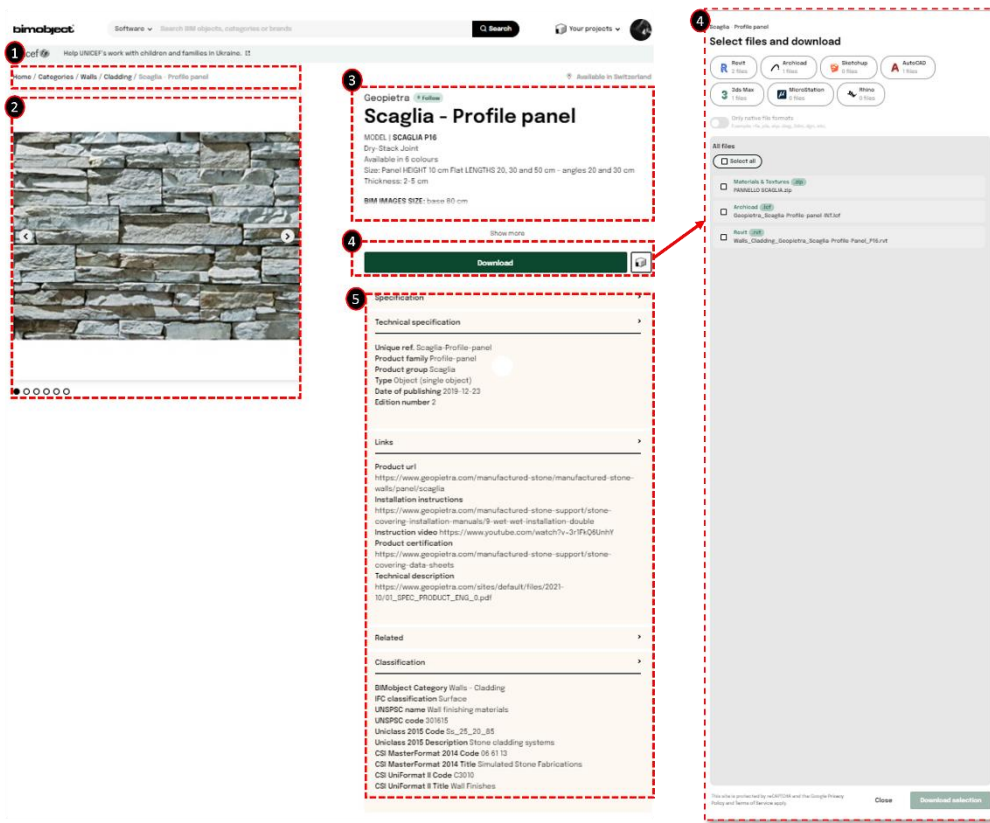


Figure 19- BIMObject User Interface

5.1.2. Core Functionality

The library's backend functionality is highlighted by its robust content management system. It has a sizable and well-organized collection of BIM objects and a breadcrumb navigation path on top of each item to understand its classification system within the library as shown in the label “1” of Figure 19- BIMObject User Interface above. Due to the platform's excellent comprehensive search and filtering capabilities, users can find items with precision and its algorithm uses more keywords from the item description to give a more robust search range. According to [trustradius.com](https://www.trustradius.com) - a technology review platform, some users have complained that the search button is untrustworthy and frequently displays irrelevant products. The keyword search is also inaccurate, making downloading families difficult. Users can create project portfolios to add BIM objects of choice in a personal shopping cart that can be revisited. The profile section contains a download history where all previously downloaded objects are curated for easy tracking.

The download is possible across different native formats for Autodesk Revit, ArchiCAD, 3Ds Max, and MicroStation as made available by each BIM object creator as highlighted in label “4” in Figure 19- BIMObject User Interface above. At the time of this research, the categories of objects covered by BIMObjects, according to its website, are materials and composite structures, standalone objects, installation products (MEP), doors and windows (residential and complex); however, this library does

not have many infrastructural elements. Many users believe that the current selection of furniture families on BIMObject is also limited, making it difficult to find specific ones. Some users wish more interior design models, such as soap dispensers, were available (Trust Radius, 2023).

The BIMObject platform has several Revit software plug-ins developed by vendors but made available accessible through the library. Devices are only supported via the web, while there are no possibilities for iOS, Android, and desktop at the time of this research.

Due to the efficient manufacturer classification system available in this library, some concerns identified by the author could include suggesting items based not only on personal preference or keywords but possibly according to paid advertisement by vendors. Data protection concerns remain valid in this case as it is across Europe. The main benefits of BIMObject include total optimized published products, basic and advanced solutions' availability, and a cloud-based environment. BIMObject consists of a plethora of features and tools. Its BIMObject Cloud module securely stores all BIM data and files, while BIMObject Apps offers comprehensive BIM tools for new and experienced developers. The BIMAnalytics Core is a lead and prospect generator that includes both direct and indirect communication tools. The BIMObject Product Site is designed for manufacturers of interior and building products. The BIMObject Hercules is designed for enterprises to develop, manage, structure, and standardise BIM objects before deployment. The BIMObject Properties define the extended property's features, such as metadata, standards, and attributes. Additionally, BIMObject consistently preserves the relevance of its content by publishing frequent updates through the content maintenance subscription service provided for manufacturers and modellers populating the library.

5.1.3. Collaboration and Interaction

A key focus of the BIMObject is to encourage user collaboration and interaction. Object URLs can be easily shared over the web, however, at the time of this research, there was no sharing feature over messengers or professional messaging platforms like teams other than sending the URL manually. It provides cutting-edge collaboration tools that let professionals exchange knowledge and insight about BIM objects through BIMAnalytics and BIMObjects Hercules. Its integrated user feedback mechanisms, which actively promote interaction and exchanging ideas, set it apart. Version control tools make it possible for project teams to collaborate while upholding the integrity of the data. Users appreciate BIMObject's variety and quality of families, making it a one-stop shop for all their project needs. Many reviewers have stated that the models downloaded from BIMObject have a high level of detail and technical specifications, which is critical for BIM projects. However, some other users complain that downloaded items are overly elaborate and heavy, making them difficult to use in large 3D models, as reviewed. They believe BIMObject requires more extensive families with multiple options for each family to make working with these files easier (Trust Radius, 2023). The distinctive strength of BIMObject is cultivating a vibrant user community that actively contributes to its growth and improvement.

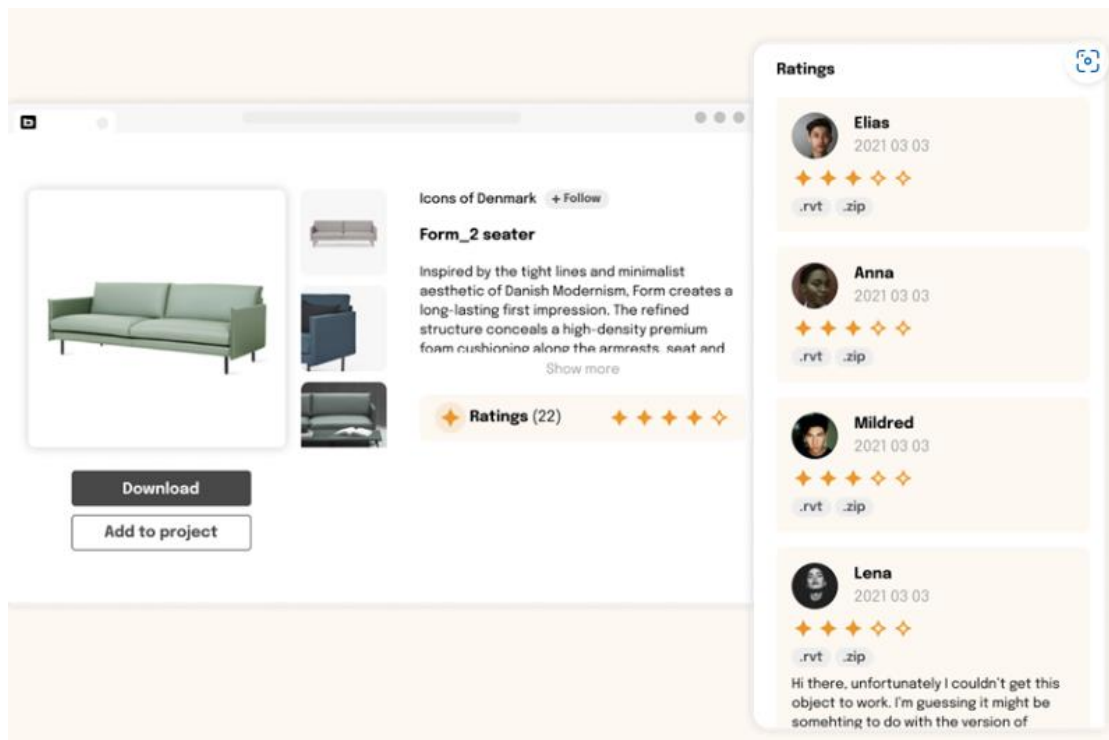


Figure 20 – BIMObject User rating and Feedback.

Users, architects, designers, and engineers on bimobject.com can rate downloaded BIM files over 5 – with the average rating being 4.2 out of 5. This gives vendors and manufacturers a direct feedback loop capable of exposing inaccuracies, complaints and irregularities encountered by direct users. This helps build low scores, better brand credibility through social proofing.

5.2. MagiCAD

MagiCAD Cloud is a cloud-based platform that provides access to a comprehensive library of Building Information Modelling (BIM) objects and data for professionals in the architecture, engineering, and construction (AEC) industry. It is closely related to MagiCAD, a well-known software suite for mechanical, electrical, and plumbing (MEP) design in a BIM environment. It allows users to create complex and data-rich models for systems such as HVAC, piping, electrical, and plumbing, allowing for more precise and efficient design processes. Its integration with BIM workflows and large library of BIM objects makes it an invaluable tool for AEC professionals looking for accuracy and efficiency in their projects. According to the official website, MagiCAD provides instant access to over 1,000,000 data-rich MEP objects from 300 of the world's leading manufacturers.



Figure 21 – MagiCAD Cloud User Interface

5.2.1. User Interface

The MagiCAD Cloud Library has an extremely user-friendly and intuitive interface. Its seamless integration with industry-standard design software, such as Autodesk Revit and AutoCAD, and its large database for MEP products distinguishes it. As highlighted by label “4” in Figure 21 – MagiCAD Cloud User Interface above, it contains a profile drop-down panel to reveal log-in details, “product request” and “collections” which is like the “Your Projects” feature in BIMobject. This integration provides users with a familiar environment for exploring BIM objects. There is an FAQ button, the MagiCAD software link and a product request button right at the top for easy accessibility. Its uniqueness stems from its deep integration with MagiCAD software as shown in label “2” in Figure 21 – MagiCAD Cloud User Interface above, which allows for a seamless transition from library search to project implementation within a single ecosystem.

The search bar contains additional filters like product type, BIM application, market area and collection to help narrow down searches better.

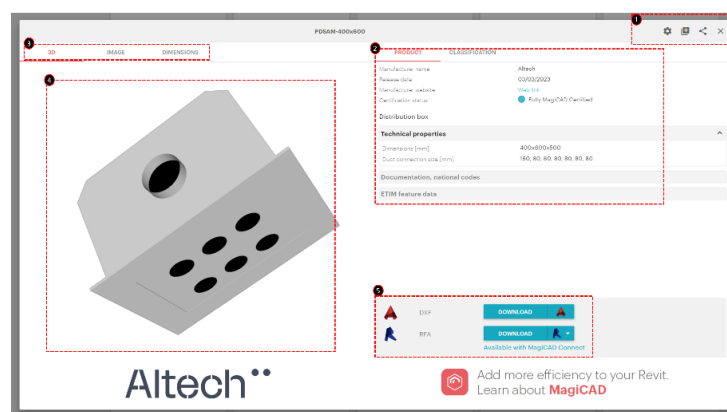


Figure 22 – MagiCAD User Interface

From the Figure 22 above, a unique feature of the library is the interactive viewing as labelled “4” where users can rotate object image in a detailed view with an option to view in 2D and isometric view with dimensions. This feature is currently absent in the BIMObject library. This feature is a useful tool for both technical and non-technical users of the library as it gives perspective into the detailed graphical representation expected in the projects. However, there are numerous occasions where the object downloaded does not in any way match the level of detail (LOD) in image shown which constitutes a level on distrust in the quality of models available on the platform as shown below in Figure 23 – MagiCAD BIM object preview vs Actual object.

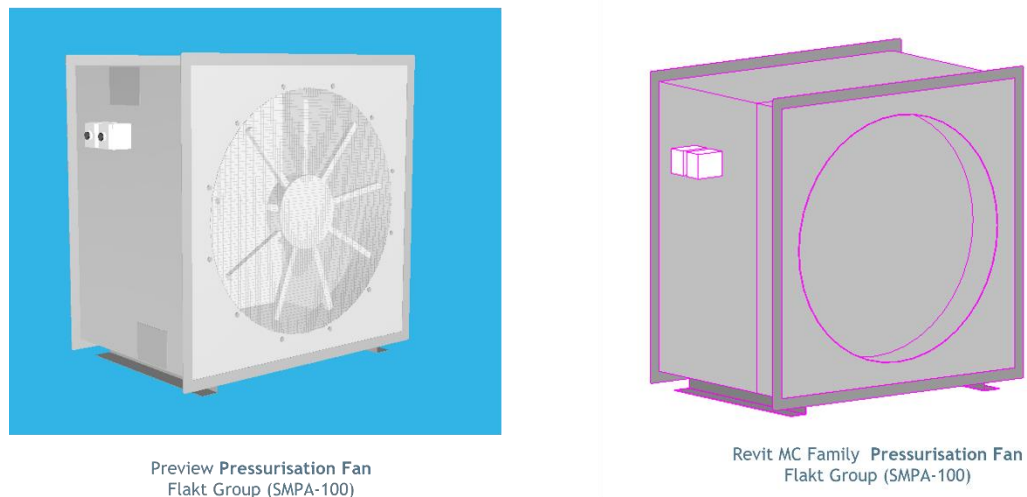


Figure 23 – MagiCAD BIM object preview vs Actual object model

As shown in label “5” in Figure 22 – MagiCAD User Interface, the download buttons for file formats available are displayed clearly at the bottom of the screen with which one click begins the download.

5.2.2. Core Functionalities

The library excels in its core functions, with a focus on HVAC, electrical, and piping systems. It distinguishes itself through its industry-specific content, which ensures that users have access to high-quality, discipline-tailored objects. The search and filtering capabilities are tailored to these domains, allowing for quick and accurate object selection. This specialization in MEP content sets MagiCAD Cloud Library apart as a valuable resource in this niche. MagiCAD's BIM objects are detailed models of physical products, with correct dimensions and technical information provided by the manufacturers. As earlier established in Figure 23 – MagiCAD BIM object preview vs Actual object above, the different discipline tools allow you to use a product library organized by manufacturer. This suggests that the MagiCAD library is also organized by LOD levels with possibility of choosing a specific product based on the reference LOD. MagiCAD object is therefore a standard library at LOD 250-300. The family previewed does not match with the model geometry. (MagiCAD show high LOD families in preview, but they are simplified objects).

The model always includes values for pressure loss, sound levels, heating and cooling capacity, and other data, allowing for accurate calculations during the design process. However, it does not allow to

close it if the balance is not finalized and closed. The use of MagiCAD functions in conjunction with BIM objects ensures that the final design performs as intended. Furthermore, MagiCAD has been localised to meet the calculation, presentation, and work-flow requirements of some of Europe's most important markets. Users can perform fully integrated pressure drop calculations, domestic water and drainage diversity calculations, and sprinkler calculations according to local standards. MagiCAD offers a variety of plugins for directly connecting manufacturers' own product selection, configuration, and sizing software into MagiCAD, however the use of MagiCAD within the Revit has not been entirely flawless.

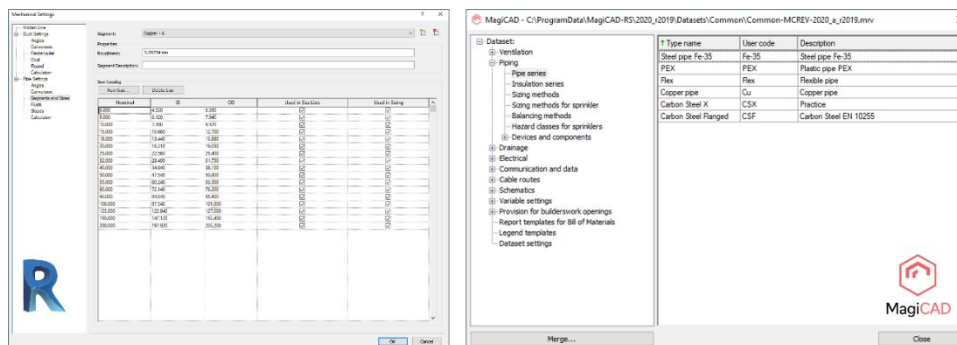


Figure 24 – Revit vs MagiCAD MEP settings

Users have reported there are different MEP settings, duplicate modelling tools that inhibits Revit features making the complete interoperability between Revit and MagiCAD difficult. MagiCAD is a software that runs on its own features and database settings but uses the Revit environment, rather than a plug-in that depends completely on Revit features and settings. It is not possible to use MagiCAD and Revit simultaneously. It is not possible to transfer MEP settings from Revit to MagiCAD because of its difference as shown in Figure 24 – Revit vs MagiCAD MEP settings above. There are other settings with the same name in both Revit and MagiCAD however execute different functions which suggests users should stick to either solution rather than anticipate a form of synchronisation. When a product, such as an Air Handling Unit, is configured using a plugin, its dimensions, symbols, connection points, and technical data can be imported into the project in RFA format.

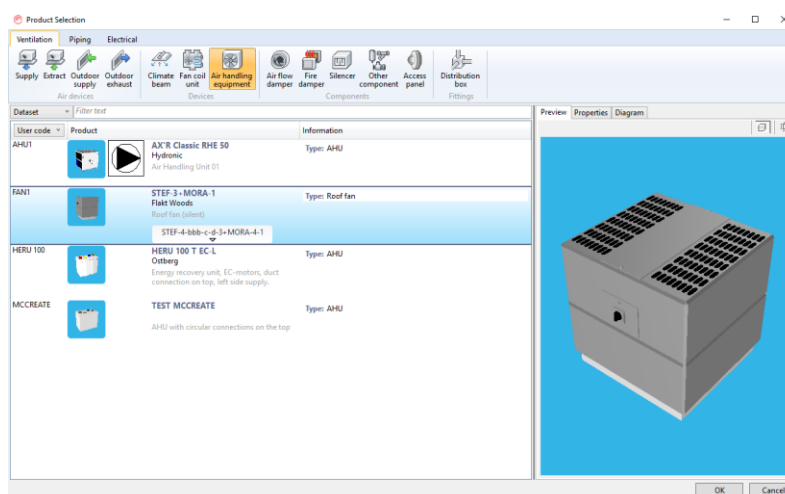


Figure 25 – MagiCAD product selection feature

The Product Selection tool is useful to choose a MEP product by brand and type available the market however only few families are customizable. It shows a rather detailed preview compared to the downloaded object. If there is a need to use products that are not available in its extensive library of ready-made BIM objects, one can download and install its simple modelling application MagiCAD Create. With MagiCAD Create, the required objects can be created by editing the generic objects in the library.

5.2.3. Collaboration and Interaction

MagiCAD dataset with software rules is an external file (.mrv) that can be used only and exclusively by the same software. This feature does not allow the creation of a relationship between Revit and MagiCAD if you want to automatically transfer the content of a MEP template from Revit to Magicad. This dataset can be shared with members of a team for collaboration purposes however it can only be accessed within the same software. Like BIMObject, objects can share using URLs with an additional button included in the top of the object selection box as labelled “1” in the Figure 22 – MagiCAD User Interface above. While the features, tools for collaboration and overall interaction are generally user-friendly, some users report a learning curve, particularly if they are new to the MagiCAD ecosystem and there is a need to bring onboard everyone you need to collaborate with.

5.3. RevitCity

RevitCity is a prominent and well-established BIM library platform, primarily tailored for Autodesk Revit users. It has earned recognition for its role in facilitating the exchange of Revit families and models within the Revit community. RevitCity is purely community-based, and it allows its users to upload their own content. RevitCity community share their families for free and let their peers decide what is good content. While this is low-hanging fruit to allow RevitCity users to rate content however the downside is having an influx of “bad” content. With hundreds or thousands of search results of BIM objects for Revit which have no rating, you won't realise you're downloading an unusable object until you've spent time opening the family in the family editor or loaded it into your project.

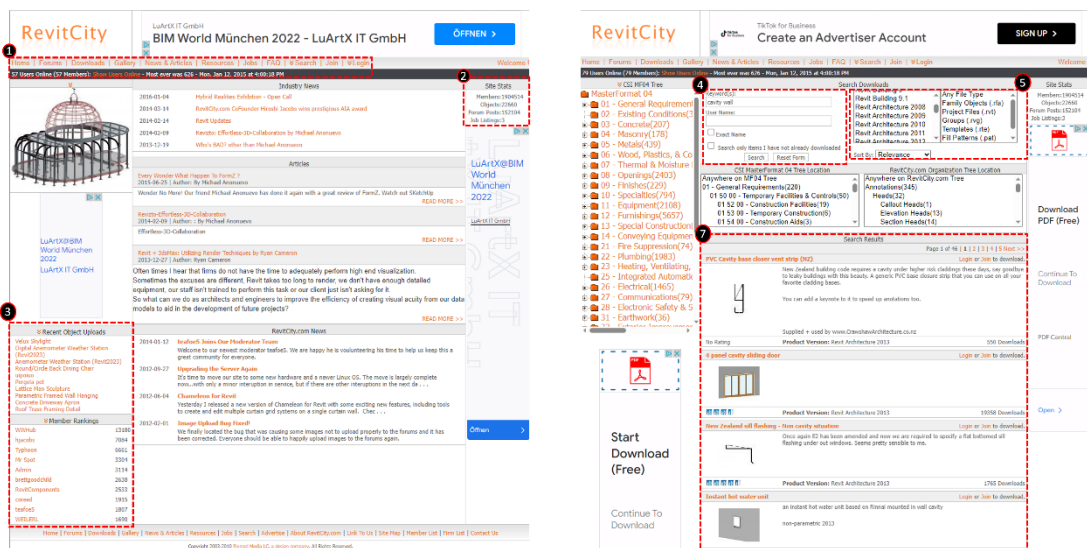


Figure 26 – RevitCity User Interface

5.3.1. User Interface

The user layout of RevitCity's is tailored towards a forum much more than a library and has not changed much in the past decade. Its user interface is primarily utilitarian, designed to serve the needs of Autodesk Revit users. The interface is straightforward, focused on functionality rather than aesthetics however because it started as a revit forum where users share content with one another, it still possesses the elementary layout design it had several years ago when it launched. In the heading labelled “1” in Figure 26 – RevitCity User Interface, there is an array of all the features contained on the platform which includes downloads where revit families are uploaded and downloaded. Its layout has a ranking for top members and recent objects downloaded corresponding to the “trending products” in BIMobjects as highlighted label “3” in Figure 26 – RevitCity User Interface above. Furthermore, label “2” shows over 1,900,000 registered members as at the time of this research which emphasizes its emergence in servicing the revit community.

5.3.2. Core Functionalities

It is worthy to note this library is predominantly revit families different from other libraries studied which had other file formats. A distinctive feature is the abundance of user-generated content. Users contribute their Revit families and models to the library, expanding its offerings and reflecting a sense of community-driven content creation. Users can search for specific Revit objects by category, family type, or keyword. Filters are provided to refine search results. While these filters serve their purpose, some users have noted that the navigation can be improved, especially when dealing with the extensive library. From the label “7” highlighted in the figure above, the search algorithm feedback displayed tonnes of irrelevant items from its downloads with only part of the keyword. There is no possibility to filter objects by rating as it lacks a credible rating system however other filters like Revit version, file type (. rfa,.rvt,.rvp,.rte), organisation tree location and CSI Masterformat 04 tree location are available. The efficiencies of these filters could not be verified as it still displays irrelevant search results. There are relatively low standardisation protocols in this library unlike the other BIM libraries studied and the only way to assess the quality of a BIMObject is by downloading it first. There is little or no description on many items and it sometimes take referral through the forum to find usable relevant BIM objects.

5.3.3. Collaboration and Interaction

The interface prominently features the community forum, encouraging user engagement. Users can participate in discussions, seek advice, and share their knowledge. Collaboration and knowledge sharing are at the core of RevitCity's ethos. Users can learn from each other, troubleshoot issues, and gain insights into best practices, enriching their Revit proficiency. This community-driven aspect of the interface fosters collaboration among members. RevitCity forum for interaction is a form of online technical support for the revit users' community, hence keeping its relevance.

5.4. NBS BIM Library

The NBS BIM Library is an essential component of the NBS ecosystem, which has a long history of providing critical information and tools to the construction industry. For more than four decades, NBS, formerly known as the National Building Specification, has been at the forefront of providing

construction-related information and standards in the United Kingdom. NBS was founded in the 1970s with the goal of creating comprehensive building specification systems to help architects, engineers, and construction professionals create accurate and standardised project documents. Its services have evolved over time to include a broader range of digital tools and resources to aid in the construction and design processes. NBS recognised the need for a dedicated BIM library that could provide architects, engineers, and designers with a rich repository of BIM objects and associated data as the construction industry evolved and adopted Building Information Modelling (BIM) methodologies. To meet this demand, the NBS BIM Library was created, which includes a wide range of BIM objects, classification systems, specifications, and collaborative tools tailored to the needs of modern construction and design professionals.

According to the official website, the NBS BIM Library is today an asset in the NBS portfolio, serving as a vital hub for BIM content and knowledge. It demonstrates NBS's dedication to assisting the construction industry in its transition to digital workflows, standardised data exchange, and collaborative project delivery. With its roots deeply embedded in the construction sector's history and evolution, the NBS BIM Library continues to play a pivotal role in shaping the future of construction through the adoption of BIM technologies and practices. It is the only repository of high-quality BIM objects that has been certified to meet the NBS BIM Object Standard.

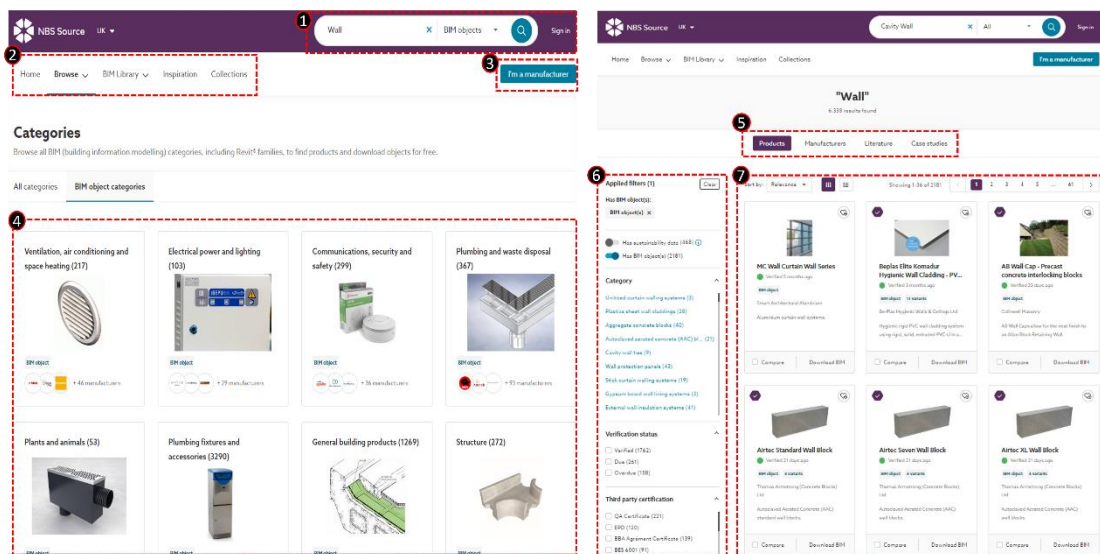


Figure 27 – NBS BIM library User Interface

5.4.1. User Interface

The user interface is simple, efficient, and intuitive, emphasising functionality over aesthetics. Its simplicity is an asset, allowing users to quickly navigate and find the required resources without being distracted by too much information, like the RevitCity homepage or the MagiCAD with brand listings on its library homepage. The entire library can easily be browsed using BIM object categories as highlighted in label “4” in the figure above. The search and navigation features on the platform are robust. Users can start searches with keywords, product names, or category names. If any case studies fit into the keyword, use the search panel option “case study” as highlighted by label “5” in Figure 27 – NBS BIM library User Interface above. The ability to filter results based on criteria such as category or

manufacturer improves search precision. This search capability is critical in a library with such an extensive collection of BIM objects. One of the UI's strengths is its seamless integration with popular BIM software, including Autodesk Revit. This integration ensures users can effortlessly incorporate selected BIM objects into their chosen BIM environment. The Revit plug-in UI also facilitates a smooth transition from library exploration to project implementation with options of previewing before downloading into the project. Unlike the MagiCAD, the plug-in operates more dependently on the Revit settings and parameters despite containing its innate standards. Search results display relevant objects in an array of thumbnails with a little description about them, a NBS BIM object standard tag, a one-click download button, manufacturer name, object verification status, a check box for multiple selections and a compare button allowing users to compare objects. This feature is unique to this library and allows deducing the difference between BIM objects without downloading. This is possible because of the standardisation and verification measures put in place.

5.4.2. Core Functionalities

At the core of the library are its extensive BIM objects. These objects encompass a broad spectrum of building components, materials, and systems developed using the NBS object standard. As an official Autodesk Solution Associate, the NBS BIM Library has a plug-in for Autodesk Revit, allowing full integration into the BIM software authoring environment. With this plug-in, objects can be downloaded from NBS directly into the project. The NBS BIM library offers customisation options, allowing users to tailor BIM things to meet project-specific requirements. This flexibility enhances the adaptability of the library's resources, ensuring that users can find and use things that align precisely with their project needs. A distinctive feature is the integration of classification standards like Uniclass. This integration enables standardised categorization of building objects, which is crucial for consistency and data exchange in BIM projects. Additionally, the library's integration with specifications allows users to select objects based on geometry and performance and compliance criteria, supporting informed decision-making as highlighted in label "6" in the figure above. Users can efficiently locate specific BIM objects using various criteria, including category, type, manufacturer, certifications, NBS BIM object standard, software platform, environmental parameters or just any keyword. This feature simplifies the process of finding the suitable objects for their projects.

5.4.3. Collaboration and Interaction

Using the plug-in, users can access the library through a web portal or directly within BIM software. This accessibility accommodates various user preferences, project workflows, and other collaborative tendencies available in the BIM software. The library's search and preview features enable users to explore and assess BIM objects efficiently, the object can be saved into a collection to create a personal catalogue. Users can inspect objects in 3D and access relevant information before downloading. The NBS BIM Library integrates with the NBS Chorus. This versatile platform assists construction professionals in creating, managing, and coordinating construction specifications and integrating with BIM for improved project coordination and compliance. BIMObjects specification can be modified collaboratively through this platform. Seamlessly integrates with BIM software, allowing users to link specifications to BIM models. This integration ensures that specifications align with the digital representation of the project, enhancing coordination and consistency.

6. BIM LIBRARY MANAGEMENT PLATFORM AND WORKFLOW

6.1. Conceptualisation

Technology advancements have transformed how Architecture, Engineering, and Construction (AEC) professionals collaborate, manage data, and access critical resources. BIM libraries, which serve as repositories for standardised digital components, materials, and systems, are essential to this technological evolution. This chapter builds on the analysis of the AS-IS workflow carried out in Chapter 4 to create a new BIM library workflow for the research company.

Purpose: The primary objective of the envisaged BIM Library platform is to function as a centralised repository for BIM objects within the Buildings Department, serving a multitude of critical purposes:

1. **Efficient Access to BIM Objects:** The platform's core function revolves around systematically cataloguing all available BIM objects across various disciplines within the Buildings Department. This meticulous categorisation ensures that all stakeholders gain effortless access to a comprehensive array of components, materials, and systems that are indispensable for their project requirements. By this systematic organisation, the platform streamlines the object selection process, effectively curbing the time and effort expended on manual object creation. Furthermore, it alleviates redundancy concerns, particularly for non-technical users, who often need help with duplicated efforts.
2. **Standardization and Regulatory Compliance:** A pivotal aspiration of the platform is to champion the cause of standardisation and uniformity within the department. This endeavour is actualised by incorporating a BIM Library - Revit plug-in, which lends automation to the meticulous BIM object review process. The Revit plug-in assumes the responsibility of ensuring that BIM objects and their specifications seamlessly conform to the stipulated company standards, industry codes, and regulatory mandates. The resultant benefit is twofold: it fosters internal consistency and adherence to company-specific documentation standards while extending its influence on external contractors engaged in collaborative endeavours.
3. **Facilitating Enhanced Collaboration:** Collaboration emerges as a pivotal tenet at the heart of the platform's mission. It empowers stakeholders with unfettered access to a wealth of BIM object data and associated properties, tailor-made for each project's unique exigencies. The platform effectuates this synergy through synchronisation, an inherent feature of the BIM library – Revit plug-in. Real-time synchronisation orchestrates seamless data updates, facilitating a dynamic and fluid exchange of modifications from the authoring tool to the web-based BIM library. Consequently, even non-technical professionals can use this collaborative tapestry, leveraging real-time access to the latest project developments to read, assess and extract BIM data without additional technical support.
4. **Seamless BIM Software Integration:** The platform envisages frictionless interoperability by seamlessly integrating with the industry-standard Autodesk Revit and AutoCAD formats. This

strategic integration design assures users that BIM objects, meticulously curated within the platform, can be effortlessly imported into the BIM environments. It effectively bridges the chasm of interoperability and propels a harmonious synthesis of BIM workflows.

In summation, the envisioned BIM Library platform embarks on a multifaceted mission. It aspires to be the central focal point for BIM objects within the Buildings Department, addressing pivotal objectives such as expediting BIM object accessibility, promoting standardisation and compliance, facilitating seamless collaboration, and fortifying its integration prowess with leading BIM software applications. This purpose-driven platform, meticulously designed and equipped, seeks to empower professionals within the department, catalysing a paradigm shift towards enhanced efficiency, reliability, and collaborative excellence within the domain of Building Information Modelling needs and other aligned project goals.

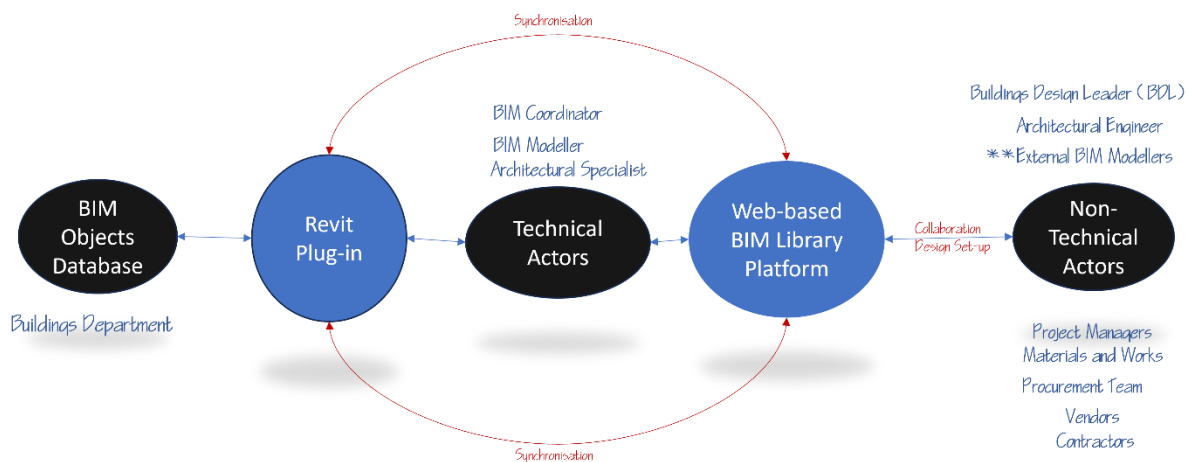


Figure 28 – New BIM library concept

Designing a BIM Library platform requires careful consideration of various design concepts to ensure it aligns with user needs, promotes collaboration, and facilitates seamless integration into the BIM workflow without major disruptions to the research company. Case studies have informed a great deal of the modifications made to the current workflow and the developed concept.

This concept centres around the technical actors (BIM Professionals) being the core of the BIM process, extending their competencies towards managing the BIM library and its interaction with non-technical actors. As depicted in Figure 28 above, stakeholders such as the Architectural engineer, project managers, procurement team, materials and works department, vendors and the Building Design Leader are considered non-technical actors due to their indirect involvement in the BIM process. The Architectural Specialist is regarded as a technical actor because of its crucial role in specifying BIM objects to be made available for any project development. The current BIM objects storage domiciled in Revit will be managed by a Revit plug-in integrated with the new web-based BIM Library platform.

While the scope of this research is limited to the workflow design and BIM library design guidelines, a prospect would be to design the Revit Plug-in and Web page software architecture to suit the proposed workflow.

6.2. TO-BE Process Map Development

The To-Be process map is a pivotal strategic tool for conceptualising and refining the envisioned operational state. Following the comprehensive analysis of the As-Is process map, which provided an illuminating snapshot of the existing workflow within the research company, the To-Be process map takes on a forward-looking perspective. It delineates the proposed future state of operations, constituting a fundamental component of this chapter's objectives. Specifically, one of the primary aims of this research is to optimise and enhance the user workflow encompassing the BIM Library within the broader context of the company's BIM processes.

Drawing from the approach utilised in constructing the AS-IS process map; the swimlane process map plays a pivotal role in this phase. It validates the proposed workflows against project requirements and objectives, facilitating stakeholder discussions and fostering consensus on the most efficient and effective processes. The TO-BE process maps, in essence, operate as a design board, bringing clarity, aligning goals, and highlighting essential requirements. These elements are foundational in pursuing a user-centric design for the BIM library, one that optimally serves the needs of stakeholders and bolsters the overall efficiency and effectiveness of the organisation's BIM processes. Swimlane Process Maps excel at visually representing workflows and role-based interactions, making them extremely useful tools for explaining and refining BIM users' workflows in the context of the new BIM library. The envisioned BIM library can be designed to seamlessly integrate with user workflows, boost productivity, and contribute to the advancement of the Building Information Modelling ecosystem of the target company.

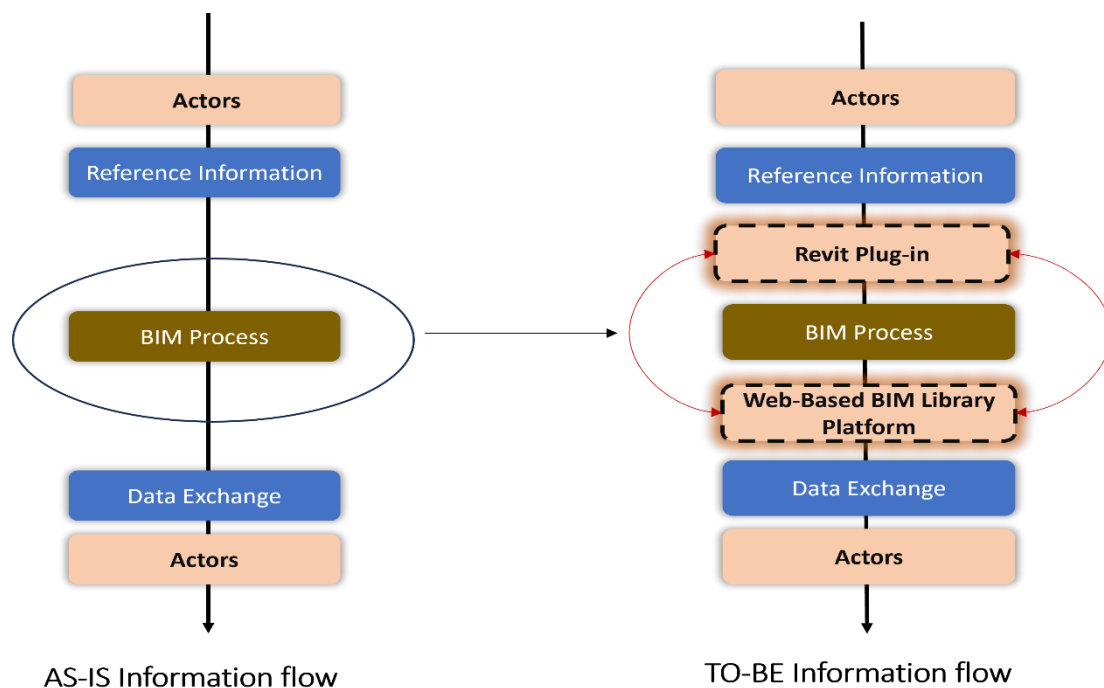


Figure 29 – AS-IS vs TO-BE Swimlane comparison

Figure 29 above explains the introduction of the Revit plug-in and Web-based BIM library to complement the existing BIM process in the company. Comparing the AS-IS and TO-BE shows that the

existing information flow is kept the same with the reference information, actors and data exchange maintaining their positional location across the project lifecycle within the department. A constant connection between the Revit plug-in and the Web platform is to be sustained for the concept to be viable.

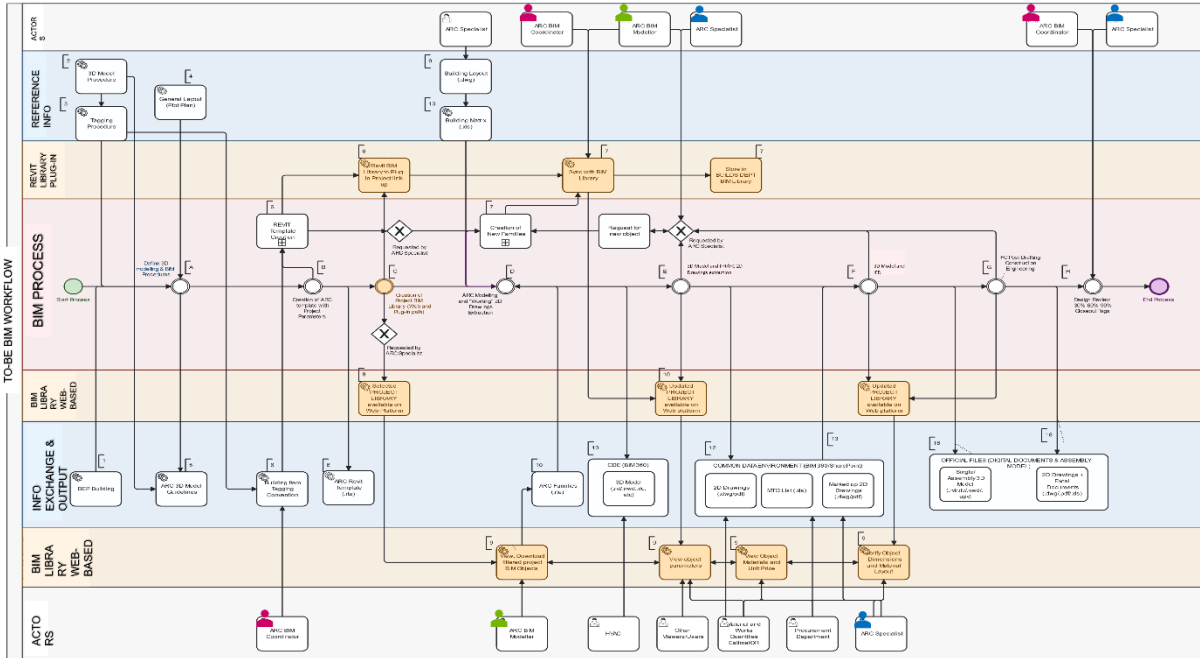


Figure 30 – TO-BE process map

As depicted in Figure 30, the newly introduced web-based BIM library functions as an intermediary between the BIM process swimlane and the information exchange swimlane. It also serves as a liaison between the actors' swimlane and the information exchange/output swimlane. The Revit plug-in swimlane bridges the reference information and the BIM process. The integration of these solutions, characterized by automation capabilities, significantly reinforces the efficacy of the BIM methodology.

The introduction of a novel process, denoted as "C," initiates the integration of these solutions into the existing BIM process within a typical project. At the stage labelled "C – Creation of Project BIM library (Web & Plug-in path)" in the process map, the inception of a new project-specific BIM library is instigated upon the request of the Architectural specialist via the web-based library. This action facilitates the provisioning of only the requisite BIM objects tailored to the unique project's requirements. In cases where the desired BIM objects are unavailable in the BIM library, a formal request is directed to the BIM coordinator for assessment and subsequent approval for creation by the BIM modeller. The BIM modeller, leveraging the capabilities of the Revit plug-in, which operates as a family manager, undertakes the task of generating the new object within the existing object category. Following the requisite approvals for the newly created BIM objects, a live trigger is initiated, rendering them accessible within the overarching BIM library.

Here, the Architectural specialist or the BIM coordinator holds the prerogative to incorporate these objects into the project-specific library as necessitated. Non-technical actors, including the Building Design Group Leader, project managers, procurement team, materials and works department, vendors,

platform's infrastructure. Some of the capabilities expected from the BIM library platform are discussed here.

- **Collaboration and Interaction:** This parameter focuses on how the BIM library facilitates real-time collaboration and interaction among project stakeholders. It's about creating a digital environment where users can share information, provide feedback, and collaborate seamlessly, improving project outcomes. Functions that enable users to are discussed here.
- **User Authentication and Access Control:** The research refers to the security measures in place to verify user identities and control their access to the BIM library. Ensuring that only authorised personnel can access sensitive project data and information is essential.
- **Administration Panel:** The administration panel is the control centre of the BIM library, where administrators manage and oversee its operations. It's where user accounts are created, content is curated, and overall system management occurs.
- **Integration with External Tools:** This parameter addresses the BIM library's ability to seamlessly connect and work with external software and tools commonly used in the research company and the AEC industry at large. It's crucial for ensuring that the BIM library integrates with existing workflows and tools to enhance productivity and collaboration.

The image below shows the metrics for the design and the equivalent number of requirements developed.

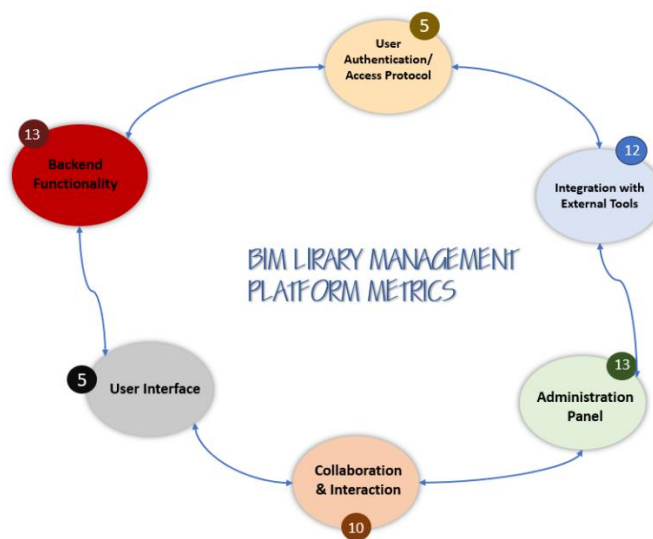


Figure 32 – BIM Library Management Platform Design Metrics

6.3.1. User Interface

a) Navigation and Layout:

- **Main Menu:** A clear main menu positioned at the top of the interface, featuring prominent buttons or tabs for core functions like "Home" – which returns a user home "Search," "Projects,"

and "My Library". These buttons should be accessible from any page within the platform, ensuring easy navigation.

- **Search Bar:** A prominently placed search bar, possibly towards the top-centre or top-right corner of the interface, allowing users to quickly search for BIM objects by keywords, categories, or other relevant criteria.
- **Breadcrumbs:** A breadcrumb trail or navigation path displayed below the main menu to help users understand their current location within the platform and easily backtrack to previous pages. It should be located around the selected item advisably on top or beneath the image.
- **Advanced Search Filter and Sorting Options:** Filters and sorting options on search results pages to refine and organize the displayed BIM objects based on discipline (ARC, M&P, E&I), object categories, object code and project name while on the sides of the page, implement an extensive set of filters that allow users to refine their searches even further based on specific criteria such as project phase, discipline, construction type, geographical location, date of commencement, and more.
- **Faceted Search:** Utilize faceted search options to dynamically update filter choices as users apply them, providing instant feedback on available options and refining search results.
- **Saved Searches:** Allow users to save their search queries for future use and receive notifications when new objects meeting their criteria are added to the library.
- **Recent Searches:** Display a list of a user's recent searches, making it easy to revisit previous queries. This can also pop up as suggestions when keywords are entered into the search bar.
- **Tagging and Labels:** Implement the existing tagging system that allows users to label and categorize objects, making it easier for all users already accustomed to the Building Tagging Convention or Project Tagging Procedure to organise and find content later.
- **Favourites or Bookmarks:** Users can mark specific BIM objects as favourites or bookmarks for quick access. This can be as simple as a small "love-shape" icon attached to the corner of the object image.
- **Recommended Content:** Provide personalised recommendations based on a user's search history, preferences, roles, companies, or the project authorisation they possess.
- **Project-Specific Libraries Page:** Allow users to view project-specific libraries or folders where they can organise and save relevant BIM objects for specific construction projects. Objects available are based on the discipline of user and authorisation level.
- **Object Versions:** Clearly indicate different versions of the same BIM object and allow users to switch between versions when necessary. This is important in cases of object review or the creation of a variance.

- **Grid and List Views:** Users can switch between grid and list views for search results, accommodating different browsing styles.
 - **Pagination and Infinite Scrolling:** Offer options for traditional and infinite pagination based on user preferences and content volume.
 - **Quick Actions:** Include intuitive icons or buttons for quick actions like downloading, adding to a project, sharing, or reporting issues with BIM objects. This can be a responsive pop-up when the mouse hovers over BIM objects displayed during a search.
 - **Contextual Menus:** Implement contextual menus that appear when users right-click, tap, and hold on an object, providing quick access to relevant actions. This menu can host other features possible to be carried out on a particular selection.
 - **Progress Indicators:** Use progress bars or indicators to show the status of downloads or uploads when users interact with BIM objects.
 - **Breadcrumb Navigation:** Display a breadcrumb trail that shows users their current location within the library's hierarchy, making it easier to navigate backwards.
 - **Custom Notifications:** Provide customisable notification settings that allow users to specify how they want to be alerted about library updates, comments, or collaboration requests.
 - **Language Selection:** Since the BIM library serves a diverse user base, offering language selection options to accommodate users from different regions will be included.
 - **Interactive Tutorials:** Include interactive onboarding tutorials or tooltips that guide users through the platform's features when they first access the library. This can also be incorporated in general onboarding videos of the organisation for roles related to the BIM library.
 - **Feedback Mechanisms:** Encourage users to provide feedback on the UI's design and functionality, allowing continuous improvements. This is important during the early stages to measure user satisfaction.
 - **Responsive Design for Various Devices:** Ensure the UI is responsive and adapts seamlessly to different screen sizes and resolutions, including desktops, tablets, and smartphones.
- b) **BIM Object Selection Display:**
- **Thumbnail Previews:** Thumbnail previews of BIM objects in search results, along with essential information like object name, category, file format and any other critical information about the object due for a first glance identification.
 - **Detailed Object View:** A click-through option to access detailed views of BIM objects, providing comprehensive information, including object specifications, dimensions, materials, and any related documentation.

- **3D Visualization:** Interactive 3D image of BIM objects, allowing users to rotate, zoom, and inspect objects from different angles for a better understanding.
- c) **User Profile Dropdown and Personalization:**
- **User Profile:** Accessible through a username as designated by the company, displaying user information, activity history, and settings options.
 - **Customization:** Options for users to personalise their profile settings, including notification preferences, language preferences, and the ability to create custom libraries or collections.
- d) **Collaboration and Interaction:**
- **Comments and Feedback:** Integration of comment sections for users to leave feedback, ask questions, or provide insights on specific BIM objects.
 - **Real-time Updates:** Notifications or alerts for users regarding collaborative activities, updates to objects, or new comments.
 - **Sharing:** Easy sharing options, allowing users to share BIM objects or project libraries with colleagues or external stakeholders via email, teams, one drive or direct links.
 - **Help and Support:** Access to a comprehensive help centre or knowledge base with FAQs, tutorials, and troubleshooting guides. This can be linked to the supporting department handling the maintenance of the platform.
 - **Accessibility:** Compliance with accessibility standards to ensure that the UI is usable by individuals with disabilities, including support for screen readers and keyboard navigation.
 - **Visual Design:** A clean and visually appealing design with a consistent colour scheme of the organisation, typography, and iconography to enhance usability and brand identity.
- e) **Security and Permissions:**
- Integration of access control mechanisms and permissions settings to ensure that users only see and interact with objects and data they are authorized to access.

6.3.2. Backend Functionality

a) Project-Specific Libraries

- **Project Library Creation:** Allow technical users to create project-specific libraries or folders to organise and save relevant BIM objects for specific construction projects.
- **Review and Synchronisation:** Enable real-time effect of reviews and modifications made through the authoring software (Autodesk Revit)

b) Data Storage and Management:

- Database Structure: Design a robust database schema to efficiently store BIM objects, metadata, and associated data according to the uniqueness of each discipline.
- Version Control: Implement version control to track changes made to BIM objects over time, enabling technical users to access previous versions.

c) Data Retrieval and Search:

- Data Indexing: Use indexing mechanisms to speed up data retrieval and search operations, ensuring quick access to relevant BIM objects.
- Full-Text Search: Enable full-text search capabilities for BIM objects based on keywords within object descriptions and documentation.

d) Scalability and Performance:

- Load Balancing: Implement load balancing to distribute incoming requests evenly across multiple servers, ensuring scalability and high availability.
- Caching: Utilize caching mechanisms to store frequently accessed data temporarily, reducing database load and enhancing system performance.
- Data Compression: Compress data during storage and transmission to optimise storage space and reduce bandwidth usage.

e) Data Security and Privacy:

- Encryption: Implement data encryption to protect sensitive information at rest and in transit. This is important when user insights and data are involved.
- Access Control: Enforce role-based access control (RBAC) to regulate who can view, edit, or delete BIM objects and data. This access should be reserved in alignment with the organisational hierarchy and as approved.
- Data Auditing: Enable auditing capabilities to track and monitor user activities and changes made to BIM objects. This is to facilitate troubleshooting in case of data or object inconsistencies.

f) Data Synchronization:

- Real-time Synchronization: Ensure that BIM objects are synchronized in real-time across the BIM library, facilitating collaboration. All changes made upon approval through authentication procedures should be made live across the respective project libraries.

- **Conflict Resolution:** Implement conflict resolution mechanisms for scenarios where multiple users edit the same BIM object simultaneously using the Plug-in to BIM library link.
- g) API and Integration:**
- **RESTful API:** Develop a RESTful API to allow seamless integration with external tools, enabling data exchange and interoperability. This is to enable integrations with future software developments.
 - **Webhooks:** Provide webhook support to notify external systems of specific events or updates within the BIM library.
- h) Backup and Recovery**
- **Regular Backups:** Schedule automatic backups of the database and related data to prevent data loss in case of system failures.
 - **Disaster Recovery Plan:** Establish a comprehensive disaster recovery plan to ensure data integrity and system availability in emergency situations.
- i) Data Migration:**
- **Migration Tools:** Develop tools and scripts to facilitate the smooth migration of data when transitioning to a new system or version.
 - **Data Validation:** Implement data validation checks during migration to ensure data accuracy and consistency.
- j) Performance Monitoring and Optimization:**
- **Logging and Monitoring:** Implement logging and monitoring tools to track system performance, identify bottlenecks, and troubleshoot issues.
 - **Optimization Strategies:** Continuously optimize database queries, indexing, and caching mechanisms to enhance system performance.
- k) Data Export and Import:**
- **Export Formats:** Support various export formats (e.g., IFC, DWG) to enable users to export BIM objects for use in other software. Other formats as required by disciplines can be included.
 - **Import Functionality:** Provide capabilities to import BIM objects and associated data from external sources or formats.
- l) Data Governance and Compliance:**

- **Data Governance Policies:** Define and enforce policies to ensure data quality, consistency, and industry compliance.
- **Data Retention:** Implement data retention policies to manage the lifecycle of BIM objects and associated data.

m) Data Analytics and Reporting:

- **Analytics Tools:** Integrate data analytics tools to extract insights from BIM object usage and user behaviour.
- **Custom Reports:** Users can generate custom reports based on their data requirements.

6.3.3. Collaboration and Interaction

When considered and incorporated into the BIM library, these parameters facilitate effective collaboration, improve user interaction, and foster a productive environment for project teams. This data can also be used to supplement technical or product documentation.

a) User Profiles and Permissions:

- **Profile Customization:** Allow users to customise their profiles with information like job roles, contact details, and profile pictures. This can be extracted from the organisation database across the current network.
- **Permission Levels:** Define different permission levels (e.g., admin, editor, viewer) to control what users can do within the library.

b) Notifications and Alerts:

- **Real-time Notifications:** Provide real-time notifications for activities such as comments, updates, or collaboration requests. This helps all users stay informed about reviews and answers to the information requested.
- **Custom Notification Settings:** Allow users to customise their notification preferences to manage the frequency and types of alerts they receive.

c) Commenting and Annotations:

- **Comment Threads:** Enable threaded comments on BIM objects, allowing non-technical users to exchange requests and feedback with technical users.
- **Annotation Tools:** Include annotation tools for users to markup BIM objects with notes or drawings for clearer communication. Marked-up image and notes should be shareable using established communication channels.

d) Revision History:

- Version Comparison: Allow technical users to compare different versions of a BIM object, highlighting changes and differences.
- Comment Integration: Link comments and annotations to specific revisions, providing context for discussions.

e) Collaborative Modification:

- Real-time Review: Support real-time collaborative review of BIM objects, ensuring that multiple users can comment, mark-up, request or save the same object simultaneously.
- Conflict Resolution: Implement mechanisms to resolve conflicts that may arise when users edit the same BIM object concurrently using the Revit plug-in to BIM library link.

f) Sharing and Access Control:

- Shareable Links: Enable users to generate shareable links to specific BIM objects or Project Libraries.
- Access Expiry: Allow users to set expiration dates for shared links, enhancing access control.

g) External Collaboration:

- Guest Access: Provide the option for external collaborators, such as clients or subcontractors, to access specific project areas while maintaining data security.
- Collaborative Permissions: Define granular permissions for external collaborators, specifying what actions they can perform.

h) User Activity Tracking:

- Activity Feeds: Implement activity feeds that display recent actions and interactions of users within the library.
- Audit Trails: Maintain detailed audit logs to track all user activities for security and accountability.

i) Project Dashboards:

- Project Overview: Offer project-specific dashboards that overview project progress, collaboration status, and key metrics. Discipline leaders should have access to discipline-wide dashboards containing individual project metrics.

- **Task Management:** Integrate task management features within project dashboards for assigning and tracking tasks related to BIM objects. Tasks should be able to synchronize with organisation calendar APIs like Teams and Microsoft.

j) User Engagement Analytics:

- **Usage Analytics:** Collect and analyse user engagement data to understand how users interact with the library and its content.
- **Feedback Surveys:** Implement feedback surveys to gather user opinions and improvement suggestions.

6.3.4. User Authentication and Access Control

a) Multi-Factor Authentication (MFA):

- **MFA Options:** To enhance login security, offer various MFA methods such as authentication apps, email verification, or biometric authentication.
- **User Setup:** Allow users to configure their preferred MFA method during account setup.

b) Single Sign-On (SSO) Integration:

- **Integration Options:** Support integration with popular identity providers (e.g., Microsoft Azure AD, Okta) to enable seamless SSO for users. This can be merged with the existing SSO protocol of the organisation.
- **Role Mapping:** Define how roles and permissions from the identity provider map to roles within the BIM library.

c) Role-Based Access Control (RBAC):

- **Granular Permissions:** Implement fine-grained RBAC, allowing administrators to assign specific permissions at the object, project, or library level.
- **Custom Roles:** Enable the creation of custom roles to accommodate unique user responsibilities within projects.

d) Access Request Workflow:

- **Request Submission:** Implement a workflow where users can request access to specific projects or objects.
- **Approval Process:** Define approval workflows for access requests, including roles responsible for reviewing and granting permissions. This should be centred around the designated technical users.

e) Access Expiry and Revocation:

- Automatic Expiry: Allow administrators to set automatic access expiration dates for users or groups.
- Revocation Process: Implement a process for revoking access when users no longer require it or when projects are completed.

f) User Provisioning and Deprovisioning:

- Automatic Provisioning: Integrate user provisioning with identity management systems to streamline user onboarding. This is to be aligned with the existing organisational identity management system.
- Deprovisioning Workflow: Implement a workflow for deprovisioning users when they leave the organization or project.

g) Password Policies:

- Password Complexity: Enforce strong password policies, including requirements for length, complexity, and regular password changes.
- Password Recovery: Provide a secure password recovery mechanism for users who forget their passwords.

h) Session Management:

- Session Timeout: Define session timeout settings to automatically log users out after a period of inactivity.
- Concurrent Session Control: Allow users to have a limited number of concurrent active sessions for security purposes.

i) Audit Trails and Logs:

- User Activity Logs: Maintain detailed logs of user activities, including login attempts, changes in permissions, and access requests.
- Security Incident Alerts: Implement alerts for suspicious activities or security breaches.

j) User Data Privacy:

- Data Consent: Obtain user consent for data processing and sharing as required by data protection regulations (e.g., GDPR).
- Data Portability: Allow users to export their personal data or delete their accounts if desired. This should be aligned with other data processing rights as established by the organisation

k) Geolocation-Based Access Control:

- IP Whitelisting/Blacklisting: Enable administrators to specify trusted or restricted IP addresses for accessing the BIM library.
- Geo-fencing: Implement access restrictions based on geographical locations or regions.

l) Guest Access Management:

- Limited Guest Access: Allow non-registered users or guests to access specific publicly shared content while maintaining security. This is important for pre-engagement between authorised users and potential contractors or vendors.
- Content Isolation: Ensure that guest access does not compromise the security of sensitive projects or data.

6.3.5. Administration Panel

a) User Management:

- User Registration: Allow administrators to manually register new users, assign roles, and configure access.
- Bulk User Import: Provide the ability to import multiple users via CSV or other formats for faster onboarding.

b) Role and Permission Management:

- Role Creation: Enable administrators to create custom roles with specific permissions to match organisational needs.
- Permission Assignment: Allow granular assignment of permissions to roles, projects, and objects.
- Role Hierarchy: Implement a hierarchy for roles, where certain roles have authority over others.

c) Project and Object Management:

- Project Creation: Give administrators the ability to create and manage projects, assign project leaders, and define access controls.
- Object Classification: Allow administrators to categorize and classify BIM objects based on disciplines, types, or other criteria.
- Object Templates: Provide the option to create object templates for consistency in data entry.

d) Content Moderation:

- Content Review: Implement a content review process, where administrators can approve or reject user-submitted BIM objects.

- Version Control: Allow administrators to manage and revert BIM object versions as needed.
- e) Data Import and Export:**
- Data Import Tools: Offer data import tools to facilitate the bulk upload of BIM objects, metadata, and project information.
 - Data Export: Enable administrators to export data and reports for analysis or backup purposes.
- f) System Configuration:**
- Customization: Allow administrators to customize the appearance and branding of the BIM library.
 - Settings Management: Provide access to system settings, including security configurations and integration settings.
- g) User Analytics and Reporting:**
- User Activity Reports: Generate reports on user activity, including login history, object interactions, and access requests.
 - Audit Trail Review: Allow administrators to review audit trails and investigate security incidents.
- h) Notification and Alert Management:**
- Notification Settings: Enable administrators to configure system-wide notification settings and templates.
 - Alert Policies: Set up alert policies to notify administrators of critical events or security breaches.
- i) Content Cleanup and Archiving:**
- Content Archiving: Allow administrators to archive projects or objects that are no longer in active use.
 - Bulk Deletion: Provide the option for bulk deletion of outdated or irrelevant content.
- j) User Support and Helpdesk:**
- Ticketing System: Integrate a ticketing system for user support requests and issue tracking.
 - Knowledge Base: Maintain a knowledge base with FAQs and documentation for administrators.
- k) Backup and Recovery Management:**

- Backup Scheduling: Schedule regular backups and define retention policies for data recovery.
- Disaster Recovery Plan: Document a comprehensive data recovery plan in case of system failures or data loss.

l) Compliance and Data Governance:

- Policy Enforcement: Ensure compliance with data governance policies, regulatory requirements, and industry standards.
- Privacy Settings: Allow administrators to configure privacy settings and data retention policies.

m) Notification and Communication Centre:

- Communication Templates: Provide predefined communication templates for system-wide announcements and notifications.
- Broadcast Messaging: Enable administrators to send broadcast messages to users for important updates or announcements.

n) Security Management:

- Security Policies: Define and enforce security policies, including password policies, data encryption, and access controls.
- Threat Monitoring: Implement threat detection and monitoring tools to protect against security breaches.

6.3.6. Integration with External Tools

a) BIM Authoring Software Integration:

- Autodesk Revit Integration: Enable seamless integration with Autodesk Revit, allowing technical users to directly modify, create, import, export and synchronise BIM objects through the Revit plug-in.
- AutoCAD Integration: Provide compatibility with AutoCAD for the easy exchange of CAD data and drawings.
- Other BIM compatible formats: Support integration with other popular BIM authoring tools like ArchiCAD, Vectorworks, and Bentley MicroStation or as necessary by various disciplines

b) File Format Compatibility:

- IFC Support: Ensure compatibility with Industry Foundation Classes (IFC) for open-standard BIM data exchange.
- DWG/DXF Compatibility: Support DWG and DXF formats commonly used in CAD software.

c) Collaboration and Communication Tools:

- Communication Platform Integration: Integrate with communication tools like the Microsoft Teams to facilitate real-time collaboration. Allowing for direct sharing of object links through emails and teams messenger

d) Cloud Storage Integration:

- OneDrive and SharePoint or others: Allow users to link their cloud storage accounts for easy file sharing and storage of BIM data. Project BIM libraries can be integrated with its corresponding project files on SharePoint. Other platforms can be integrated based on company preferences.
- Version Control: Ensure that changes made in the cloud storage are reflected in the BIM library and vice versa.

e) Data Visualization and Reporting:

- Business Intelligence (BI) Tools: Allow users to export BIM data to BI tools like Tableau or Power BI for advanced data analysis and visualisation.
- Custom Reporting: Enable users to generate custom reports using external reporting tools.

f) Data Mapping and Transformation:

- Data Mapping Tools: Offer tools to map and transform data between different formats and standards for seamless data exchange.
- Data Validation: Implement data validation mechanisms to ensure data consistency during transformation.

6.3.7. Future Possibilities**a) Virtual Reality (VR) and Augmented Reality (AR):**

- VR/AR Integration: Facilitate the visualisation of BIM objects in VR or AR environments for immersive design reviews and presentations.
- 3D Model Export: Provide options to export 3D models for VR and AR applications.

b) Project Management Software Integration:

- Project Management Platforms: Integrate with project management tools like Microsoft Project, Trello, or Asana for streamlined project coordination.
- Task Synchronization: Enable synchronisation of tasks and milestones between the BIM library and project management software.

c) APIs and SDKs:

- Open APIs: Provide open APIs that enable developers to build custom integrations with the BIM library.
- Software Development Kits (SDKs): Offer SDKs to assist third-party developers in creating plugins or extensions.

7. CONCLUSION

In the landscape of 2023, the intricate design processes within the Architecture, Engineering, Construction, and Operations (AECO) industry necessitate a heightened level of collaboration and coordination among a multitude of stakeholders, each contributing their distinct expertise. The contemporary technological milieu, characterized by the evolution from intricate programming to the emergence of low-code and no-code platforms, signifies a deliberate effort to democratize access to technical solutions. This shift is driven by the imperative to accommodate individuals from diverse backgrounds, bridging the chasm between the technically adept and non-technical stakeholders. This inclusive approach extends to industries such as AECO, where the democratization of data accessibility is pivotal. In this context, the efficacy of collaboration hinges profoundly on the seamless exchange and accessibility of information. The BIM library emerges as a potent solution to bridge the inclusion divide within any BIM-centric organization. It assumes the role of a unifying nexus, equipped with indispensable features meticulously tailored to meet the requisites of both technical and non-technical constituents within the organization. This paradigm shift in BIM library design ushers in an era of enhanced accessibility, ensuring that vital data is readily available and comprehensible to all stakeholders, thereby fostering a more inclusive and collaborative environment.

This study embarked on a comprehensive exploration of the intricate realm of BIM libraries. Its central objective was to formulate robust guidelines for the establishment and administration of a BIM library finely attuned to the intricate requisites of a large-scale design, engineering, and construction company. The expedition traversed throughout this research has provided us with a wealth of insights into the practical challenges faced by professionals working in diverse teams and navigating the complex landscape of BIM libraries. These insights, meticulously documented within, converge to shape a compelling and well-rounded output. The research was meticulously structured to fulfil a set of distinct yet interconnected objectives. These objectives, from the inception of this investigation, were to:

1. Illuminate the current workflow within the organization, providing an in-depth comprehension of its BIM processes.
2. Scrutinize the existing BIM object storage and retrieval system, evaluating its efficiency.
3. Undertake a profound case study analysis of analogous BIM object libraries in public domain, culminating in the distillation of best practices.
4. Synthesize the findings to craft comprehensive guidelines for the development and governance of a purpose-built BIM objects library, customized to meet the organizational imperatives

Through meticulous analysis, this research uncovered critical findings that bear substantial implications for the organization and the broader domain of BIM libraries. Some of these findings are listed below:

- One of the notable findings gleaned from this research pertains to the utilization of methods reliant on technical expertise for the storage and retrieval of BIM objects. This approach engenders a pronounced disparity, compelling non-technical stakeholders to depend directly on their technically proficient counterparts for access and assistance. This phenomenon has the

consequence of creating bottlenecks within the envisioned information exchange framework that underpins the BIM methodology.

- Gaining profound insights into the organization's existing workflow through document analysis, user feedback and other observational methods pinpoint areas for optimization, particularly user interface, BIM object accessibility and updates. It helped delineate an optimized workflow through the introduction of the BIM library management platform. This initiative lays the foundation for well-informed process enhancements that can be further developed.
- With case studies encompassing a national BIM library, a manufacturer-centric library, and a community-driven library, synthesis yields a repository of best practices, signifying the commitment of diverse institutions to foster the development of standardized BIM libraries. This comprehensive analysis has also shed light on the significance of essential metrics such as User Interface, Core Functionalities, Collaboration, and Interaction, which can be readily applied to BIM libraries at the organizational level.
- The development of a robust set of guidelines for the establishment and administration of a dedicated BIM library management platform, addresses aspects such as user interface, backend functionality, collaboration, access control, administration, and integration with external tools.

As recommendations, it is imperative that the organization initiates the practical implementation of the guidelines formulated in this research, commencing with the development of the BIM objects library management platform. Furthermore, a commitment to ongoing monitoring, evaluation, and refinement is advised to ensure the library's continued alignment with evolving needs and industry standards. A technical evaluation of the software engineering required to achieve these platform development guidelines is also recommended.

Nonetheless, as we peer into the horizon of technological progress, one cannot help but ponder: will BIM objects evolve to encompass a higher degree of intelligence? Might they possess the capacity to seamlessly adapt to their surroundings, particularly within BIM libraries? Or the reverse will be the case where the BIM libraries adapts intelligently to its content? Will national and international standards be developed in Large Language Models that enables it to be intelligently integrated into BIM libraries and BIM objects? This provokes yet another intriguing question regarding the potential emergence of intelligent BIM libraries that can proactively propose suitable BIM objects based on the existing BIM model, thus opening a vista of possibilities for the future.

These prospects beckon as potential subjects for future research endeavours. Until then, it is pertinent to recognize that BIM libraries can be enhanced through the incorporation of existing technologies like Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (XR), thereby engendering a more interactive and immersive experience, particularly for technical users and, crucially, for those who may lack technical expertise.

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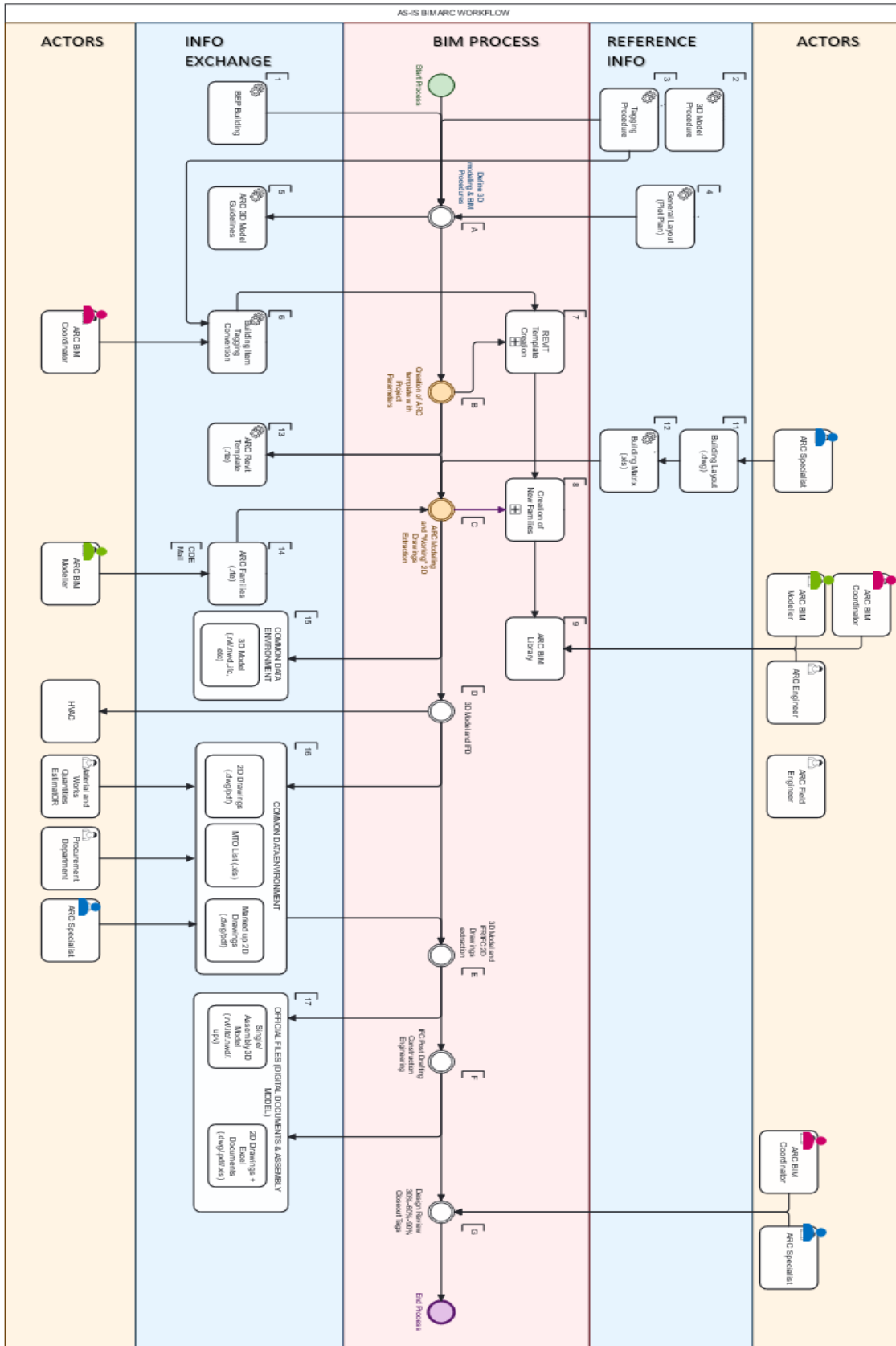
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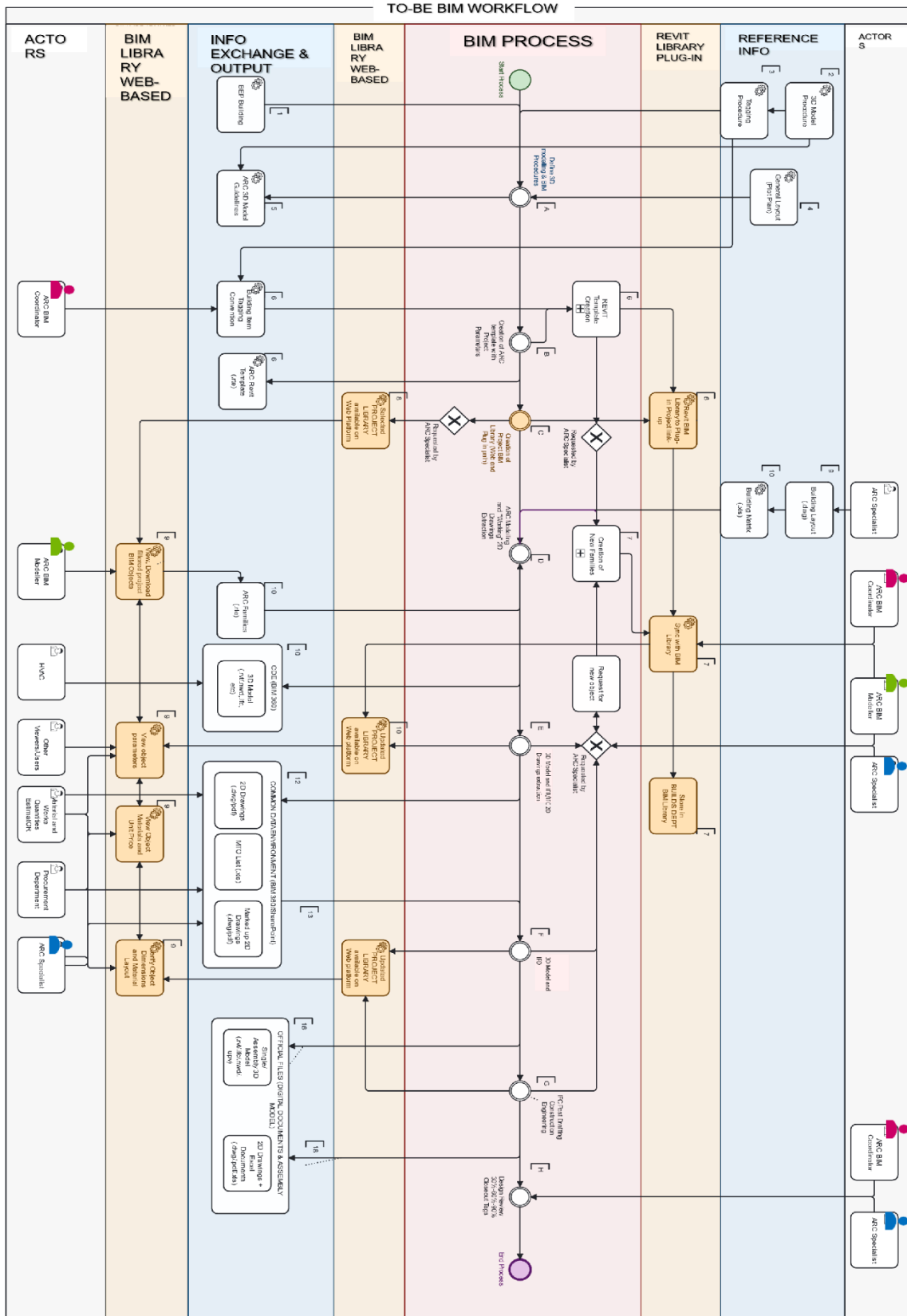
LIST OF ACRONYMS AND ABBREVIATIONS

AR	Augmented Reality
BIM	Building Information Modelling
ARC	Architecture or Architectural
BEP	BIM Execution Plan
CDE	Common Data Environment
CDE	Common Data Environment
E&I	Electrical and Instrumentation
FAQs	Frequently Asked Questions
HVAC	Heat, Ventilation, Air Conditioning
IFC	Issue for Construction
IFD	Issue for Design Development
IFR	Issue for Review
IP	Internet Protocol
M&P	Mechanical and Piping
MFA	Multiple Factor Authentication
MR/WR	Discipline Materials & Work Quantities Estimating & Management
Specialist/Engineer	Specialist/Engineer
MTO	Materials Take-Off
PEM	Project Engineering Manager
PIM	Product Information System
RBAC	Role-Based Access Control
SSO	Single Sign-On
VR	Virtual Reality
XR	Mixed Reality

APPENDIX 1: AS-IS PROCESS MAP



APPENDIX 2: TO-BE PROCESS MAP



APPENDIX 3: SURVEY QUESTIONS

Survey questions have been extracted from the online form and added below

Section 1

Introduction (Getting to know the background context of respondent)

1. Full name:
2. Job Designation/Role:
3. How do you interact with the Architectural BIM library? Why do you consult the Architectural BIM library? e.g. (for procurement details, for energy calculations, for 3D modelling, for Design, for costing & estimation...etc.)

Section 2

Ease of Use and Navigation (This section is about how easy it is to use this BIM library and to browse through.)

4. How would you rate the overall user experience of the BIM library? (Record your overall experience with the BIM library). Rated from Poor (1-10) Excellent
5. How easily do you locate and find the desired BIM objects or content? (When it comes to your line of work with the library, how easy is it to locate and retrieve the needed object). Rated from very difficult (1-10) very easy
6. Are the current navigation and search functionalities intuitive for your daily use? (Ease of using the various search features and overall navigation). Rated from Poor (1-10) Excellent
7. What specific improvements or features would you suggest enhancing the ease of use and navigation within the BIM library?

Section 3

Content Availability and Quality (This is about the quality of the object models and its availability for use)

8. How satisfied are you with the availability of BIM objects and content in the library? Rated from Not Satisfied (1-10) Very Satisfied
9. How would you rate the quality and accuracy of the BIM objects available in the library? (Does it often give you the information you seek? Does it look like what it's meant to represent?) Rated from Not Accurate (1-10) Very Accurate
10. How often do you encounter issues related to outdated or incorrect objects or item information within the library? (e.g., walls not having the correct data, windows having wrong tags, new objects not available when needed). Rated from very often (1-10) rarely
11. Are there any specific content standards or classification you would suggest for the improvement of your scope of work using the Architectural BIM library? (Any suggestion that

you think can improve the accuracy, quality and even availability of this BIM library for your use)

Section 4

Search and Filtering Functionality (This section captures the system of sorting, querying and finding a new model/object for use)

12. How do you access the library? (Depending on your scope of work, how do you access the objects library. Tick all applicable)
 - a. Directly through the Revit template
 - b. Through the Autodesk BIM 360
 - c. Through the Excel register
 - d. Through DWG files
 - e. Others
13. How effective is the search function in helping you find the desired Architectural BIM objects? (The use of the Excel database, Revit object model template, Autodesk 360 platform or any other method used to access the library) Rated from Not effective (1-10) Very Effective
14. How useful are the filtering options in reducing the search results? Rated from Not Useful (1-10) Very Useful
15. How often do you encounter challenges or limitations while searching for specific BIM objects or content? (Which leads to a delay, doubts or a need to call someone else e.g. BIM Coordinator for clarity) Rated from Very often (1-10) Rarely
16. Are there any additional search or filtering features you would like to see in the Architectural BIM library? (Which can considerably make your work easier when searching and filtering through the library)

Section 5

Interoperability and Integration (How this library inter-operates or integrates with other software used.)

17. Do you have other software you use directly with the Revit Architectural BIM Library to improve your work? e.g Revit, CPM, Energy Analysis software etc. YES/NO
18. For a NEW BIM workflow, what other suggestions of improvements or enhancements for interoperability with other BIM software platform do you want? (It can be to improve current workflow or perhaps a completely new workflow)
19. What other software do you use directly with the objects of the BIM library? Other software used in direct relation to the contents of the library (e.g., Civil 3D, 3Ds Max, Enscape, Lumion)
20. What features do you suggest implementing in the Architectural BIM library to ensure interoperability with your other software? (Give as many suggestions as possible and any possibilities on how it can be achieved)

Section 6

Collaboration and Sharing (How you work together and share library contents with other users)

21. How would you rate the effectiveness of the BIM library in facilitating collaboration and knowledge sharing (Ease of sharing objects of interest with others, or possibility of working together through the library) Rated from Not Possible 1 -10 Possible and Effective.
22. Have you collaborated with other team members or stakeholders through the TCM Architectural BIM library? If yes, how was your experience?
23. Are there features of collaboration and sharing you wish are available for the New BIM Library? (e.g., file export formats, shareable to objects e.t.c.) (Give suggestions and any possibilities of how to achieve it)

Section 7

Content Management and Updates (General management of library content and Update)

24. Do you encounter any difficulties in version control or managing updates to Architectural BIM objects? YES/NO
25. If yes, what are the difficulties encountered
26. What improvements would you suggest for better content management and updating of BIM objects within the Architectural BIM library?

Section 8

User Support and Documentation (Guide for users and technical support availability)

27. How helpful is the provided documentation or user guide for understanding and utilizing the BIM library? (Rate the overall user support and documentation). Rated Not Helpful (1-10) Very Helpful
28. How adequate is support or assistance when encountering issues or questions related to the library? Rated from Not Accurate (1-10) Very Accurate
29. Are there any additional resources or support channels you would like to have for using the BIM library effectively? Please suggest any that makes supporting you easier.