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A Framework of Information Sharing Platform for Prefabricated Building Supply Chain Based on BIM

Min Zhang, Yanxiao Bian*

School of Management Science and Information Engineering, Hebei University of Economics and Business, Shijiazhuang 050061, Hebei, China

**Author to whom correspondence should be addressed.*

Abstract: In view of the imperfect supply chain management of prefabricated building, inadequate information interaction among the participating subjects, and untimely information updates, the integration and development of BIM technology plus the supply chain of prefabricated building is analyzed, and the problems existing in the current supply chain and the application of BIM technology at various stages are elaborated. By analyzing the structural composition of the prefabricated building supply chain, an information sharing platform framework for prefabricated building supply chain based on BIM was established, which serves as a valuable reference for managing prefabricated building supply chains. BIM technology aligns well with assembly construction, laying a solid foundation for their synergistic development and offering novel research avenues for the prefabricated building supply chain.

Keywords: BIM technology; Supply chain management; Prefabricated building; Information flow

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1. Introduction

Prefabricated buildings revolutionize modern construction with standardized designs and assembly-based methods, boosting efficiency and quality [1, 2]. The Ministry of Housing and Urban-Rural Development's 14th Five-Year Plan emphasizes the advancement of prefabricated construction standards and automation [3]. Despite these benefits, the construction process is complex due to various participants and constraints [4].

Current information technology in construction hinders supply chain efficiency [4]. BIM technology offers a solution for improved information flow, with applications in risk and cost management [5, 6]. However, comprehensive BIM-based supply chain management for prefabricated buildings is lacking. This study developed a BIM-based information-sharing platform for the prefabricated building supply chain, ensuring timely and accurate information exchange [7, 8]. This platform integrates project data, enhancing collaboration and objective achievement for all stakeholders.

2. Related work

2.1. BIM technology

Building Information Modeling (BIM) is a digital standard in the building industry, leveraging 3D models to enhance design, construction, and operation processes [9]. BIM supports collaboration and allows for visual decision-making. It extends beyond 3D with time (BIM4D), cost (BIM5D), sustainability (BIM6D), and facility management (BIM7D) dimensions. Researchers have developed a life-cycle BIM maturity model with guidelines for achieving full BIM integration [10].

2.2. Construction supply chain

Supply chain management research originally centered on manufacturing but expanded to construction in the 1990s with Koskela's work [11]. The construction supply chain broadly encompasses all activities and organizations from project initiation to completion, including maintenance and building lifecycle stages [12]. It is categorized into external and internal chains, with the external chain forming a network around the contractor, connecting various stakeholders through logistics, information, and finance (**Figure 1**).

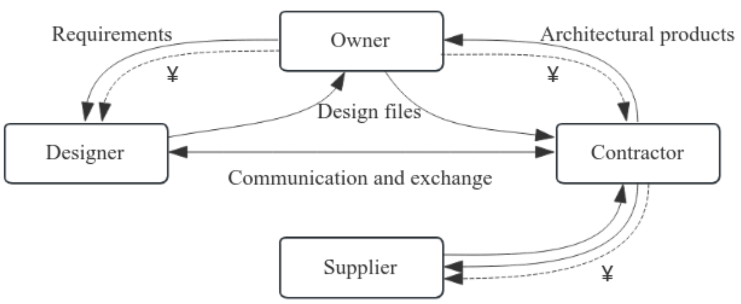

Figure 1. Supply chain of construction industry

The internal supply chain, on the other hand, comprises the various functional departments within a construction company that are related to the construction project. It involves the collaboration of departments such as finance, cost, and technical teams, which are interconnected through logistics, capital flow, and information flow. This network structure enables these departments to work together towards achieving the project's objectives.

2.3. Supply chain management model for prefabricated building

2.3.1. Prefabricated building supply chain analysis

The lifecycle-based prefabricated building supply chain encompasses decision-making, design, production, storage, construction, and maintenance stages. Developers assess projects and establish bidding intentions during the decision stage. Design units integrate BIM and intelligent cloud design, involving manufacturers and construction units. General contractors ensure component constructability and quality, coordinating production and procurement with strict quality control. Storage and transportation use BIM to ensure component integrity. Post-construction, developers handle sales and recycling, aligning with sustainability.

The prefabricated supply chain, distinct from traditional ones (**Figure 2**), features shorter construction cycles, factory production, and on-site assembly. It involves multiple parties with high information sharing and coordination levels.

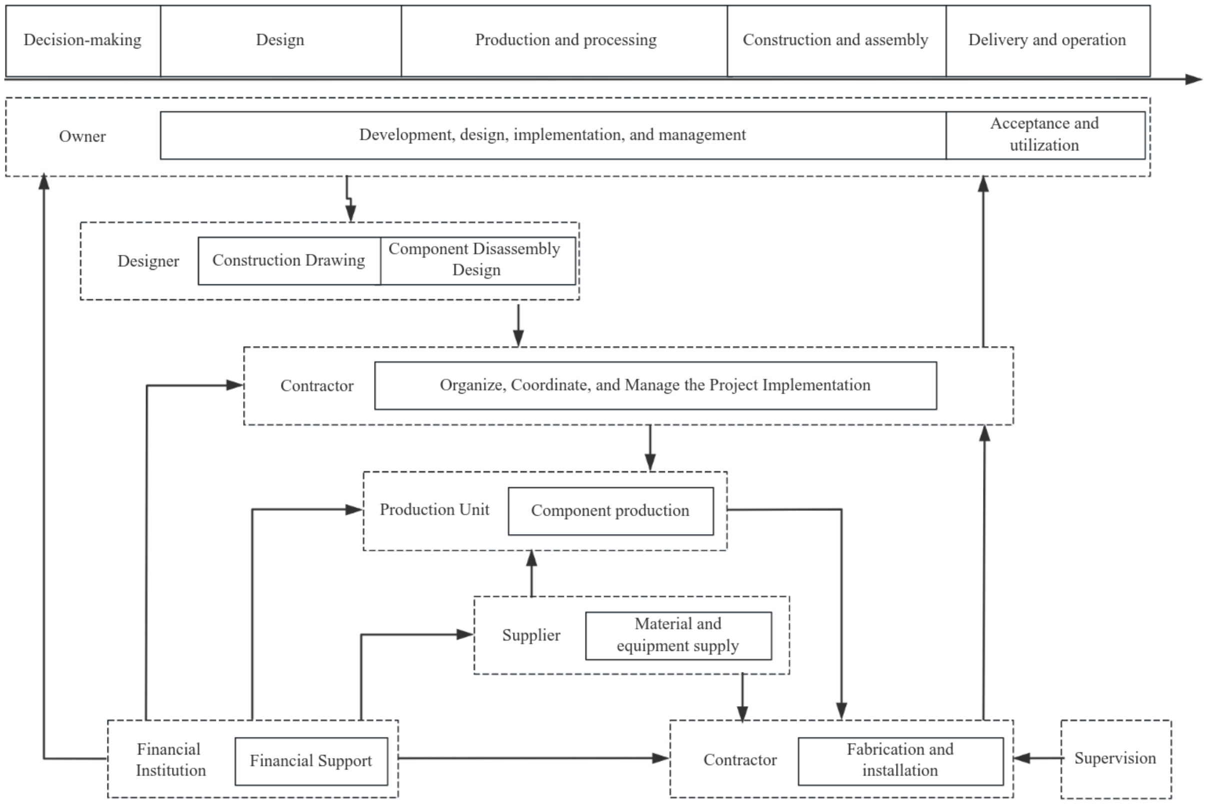

Figure 2. Supply chain of prefabricated building

The flow of information in the supply chain of prefabricated building is a two-way flow that possesses a certain order. As can be seen from **Table 1**, the amount of information required by each participating party is large and the information interaction between the participants is closely linked. Amongst other things, the information flow has the following characteristics:

Table 1. Information flow of relevant parties involved in the supply chain of prefabricated building

Participating parties	Synergistic parties	Information needed	Information submitted
Owners or developers	Designers; Contractors	Overall project planning, documentation contracts, investment and progress control reports, etc.	Project master plans, master investment mandates, owner change and confirmation orders, etc.
Designers	Owners or developers	Project opportunity feasibility studies, design briefs	Preliminary construction documents and construction drawings, information on design changes, etc.
Contractors	Owners; Designers; Prefabricated component manufacturers	Document contracts, construction drawings, design briefs, material and equipment supply schedules, owner's change and confirmation orders, etc.	Progress, quality, cost and other planning statements
Prefabricated component(PC) manufacturers	Designers; Contractors	Construction schedule control plan, material and mould supply plan	PC production completion nodes, component transport plans
Logistics transporters	Designers; Prefabricated component manufacturers	Actual site progress, PC production completion nodes	PC transport planning, storage planning

The supply chain information in construction is vast and diverse, originating from various sources including construction, supervision, supply, production, design, and government entities. It encompasses structural, electrical, and HVAC aspects, as well as management areas like investment, scheduling, environment, risk, contracts, and quality. The information is extensive and varies in format, such as engineering drawings, progress diagrams, and quantity forms, with complex interdependencies and constant updates due to the construction environment and uncertainties.

2.3.2. Current status of the supply chain management model for prefabricated building

The supply chain of prefabricated buildings, encompassing engineering and manufacturing, significantly differs from traditional models. Its multi-stage nature results in complex, dynamic, and intertwined information networks, complicating management. Despite efforts to integrate prefabricated buildings with supply chain management, several issues persist [13].

(1) Inadequate coordination and cooperation among supply chain entities

The prefabricated building supply chain involves owners, constructors, designers, supervisors, and component producers. Each entity plays a crucial role, and issues in any segment can disrupt the entire chain. Effective coordination among these departments remains a critical challenge.

(2) Information asymmetry

With numerous nodes in the supply chain, companies rely on node-specific information for raw material procurement and goal setting. However, limited inter-departmental information exchange leads to discrepancies, exacerbating over time. This asymmetry, especially at the supply chain ends, can have severe repercussions. The complexity of prefabricated building supply chains amplifies this issue, potentially leading to cascading errors.

(3) Improper connection between logistics and construction process

Logistics, influenced by time and space, accumulates errors sequentially. Initial problems impact subsequent stages, disrupting the entire construction process. Factors such as natural disasters, storage requirements, product quality, delivery schedules, casualties, geological conditions, and material delivery timings further complicate this connection.

(4) Contradiction between a single source of information and multiple information needs

Decision-making in prefabricated building supply chains demands extensive information. Multiple actors with high information needs complicate this process. While individuals can gather internal and external data or request it from various nodes, the quality of information varies based on the subject's qualifications, resources, and technical capital. This often fails to meet the diverse information needs of supply chain participants.

2.4. The application of BIM technology in supply chain management of prefabricated building

2.4.1. Information integration of BIM technology in supply chain

BIM technology provides technical support for the integration of information technology in the design, production, transportation, construction, operation, and maintenance stages of prefabricated building. It coordinates the relationship between various subjects and establishes a new cooperation model to ensure the quality of the project to the maximum extent and avoid causing waste of funds, while mobilizing the community to promote the application of prefabricated building [14]. The information sharing platform framework of prefabricated building supply chain based on BIM is depicted in **Figure 3**.

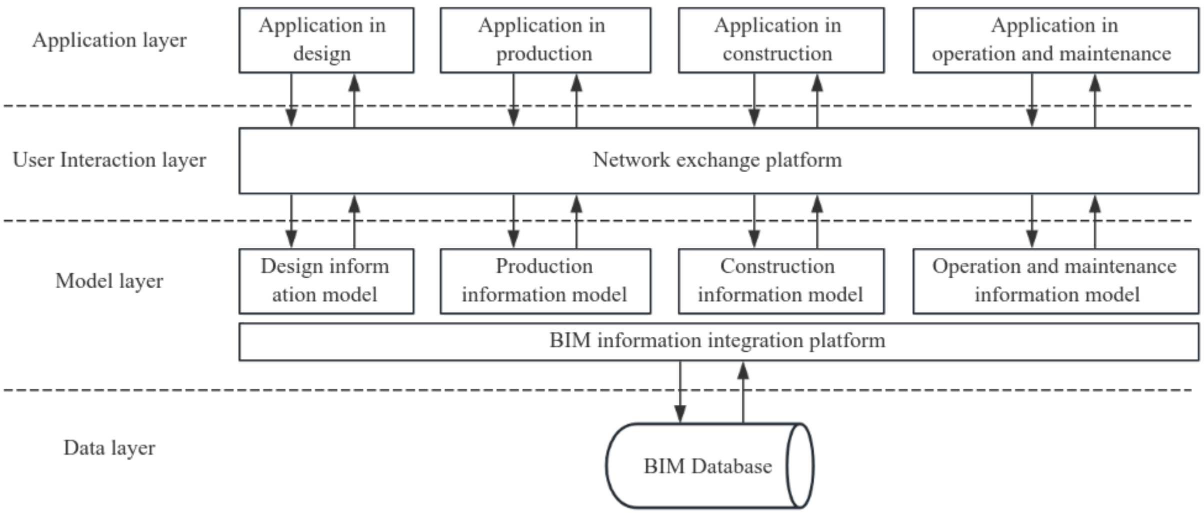

Figure 3. The information sharing platform framework for prefabricated building supply chain based on BIM

The construction supply chain involves vast and intricate information, spanning the entire building project lifecycle from planning to operation. BIM serves as the core, integrating data from various stakeholders (survey, design, construction, etc.) via an interactive platform to manage complex information flows [15]. The following steps and key points can be followed to achieve SCI in BIM:

(1) Define integration goals

Establish clear objectives, such as enhancing efficiency, reducing waste, and optimizing resources. Identify specific BIM data to integrate, like material lists and labor plans.

(2) Select appropriate BIM and supply chain management software

Choose BIM software (e.g., Revit, ArchiCAD) with strong compatibility and supply chain management software (e.g., Oracle, SAP) that integrates seamlessly with BIM [16].

(3) Data standardization and information sharing

Develop unified standards (e.g., IFC) for data exchange. Set up a platform for real-time synchronization of BIM and supply chain data.

(4) Implement integration of BIM model and supply chain software

Use APIs or ODBC to link BIM and supply chain software, enabling automatic import of design data to generate accurate material and labor plans.

(5) Application and optimization of supply chain information

Leverage supply chain software's analytics to analyze BIM data, identify issues, and optimize processes, such as material procurement and inventory management.

(6) Continuous information updates and collaborative work

Ensure real-time updates of the BIM model are reflected in supply chain plans. Utilize the BIM platform for collaborative viewing and decision-making to ensure project smoothness [17].

By adhering to these steps, SCI in BIM enhances supply chain transparency and efficiency, crucial for project success.

2.4.2. Secondary development of Revit

Through Revit's secondary development, tailored functions can be created to facilitate project supply chain participants' access to product information and enhance design data integration. The Revit API supports these developments, allowing integration of external software functions, thereby improving software connectivity and tightening project supply chain management. It also aids in managing model parameters and graphical data [18].

Revit's secondary development is confined to the .NET platform, with the API supporting all NET-based programming languages. These codes are compiled in .NET IDEs, primarily Visual Studio and Sharp Develop. Visual Studio, a widely-used Windows IDE, is ideal for coding, debugging, testing, and deployment, hence Visual Studio Community 2020 was selected for Revit's secondary development.

To begin, set up the development environment in Visual Studio, including essential plugins. The Add-In Manager is crucial for managing other plugins during runtime. Revit Lookup aids in querying element information, assisting developers in optimizing their code [19, 20]. The setup process is illustrated in **Figure 4**.

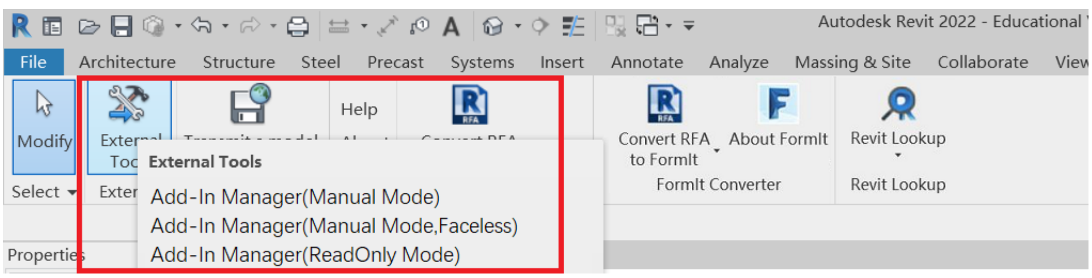

Figure 4. Construction of Revit secondary development environment

After building the development environment, the project can be started, and the business logic code can be written. In terms of software selection, the BIM model of this paper is created in Revit2022 version, and the secondary development of Revit uses Visual Studio Community2020 version, using C # as the development language [21]. The specific Revit secondary development process is shown in **Figure 5**.

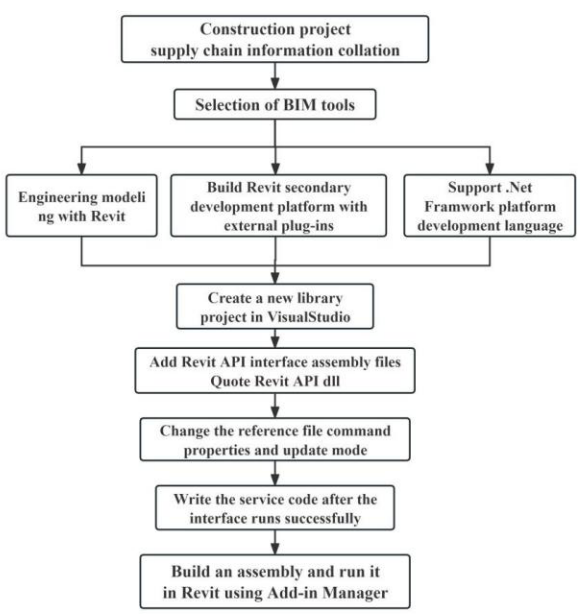

Figure 5. Flow chart of Revit secondary development

In Revit, building information model components encapsulate core data like structure size, material, and function through attributes [22]. Parameters, categorized as instance and type, organize this data effectively: instance parameters apply to specific component instances, while type parameters affect entire component types [23]. Beyond replicating design drawing data, the model integrates component identification, contractor details, and material specifications. As the project progresses, additional data such as construction progress and quality inspections can be incorporated, enhancing the model's data richness. This integration is achieved by setting instance parameters, facilitating comprehensive information management. To simplify participants' access to product information, Revit's secondary development is employed, with relevant code detailed in **Table 2** below:

Table 2. Revit secondary development code

```
Define an external command class
  Set the transaction mode to Manual
  Set the regeneration option to Manual
  Set the journaling mode to NoCommandData
  Define the Execute method for the external command
    Retrieve the application and document object from commandData
    Let app be the commandData.Application
    Let doc be the document of the active UI document

    Get the active UI document and the selection set
    Let uiDoc be the active UI document
    Let selection be the selection set of uiDoc

   Collect the IDs of all selected elements
    Let selectedIds be the element IDs retrieved from selection.GetElementIds()

    Check if any elements are selected
    If (selectedIds.Count == 0)
      Display a message box stating "Please select at least one element."
      Return Result.Failed

    Loop through each element ID in selectedIds
      Let element be the element in doc with the specified ID
      Let info be a string containing element information
      info += "Element info:\n"
      info += "Type name/Named Object: " + element.Name
      info += "\nID: " + id.ToString()
      // The following lines should be adjusted based on the actual element type and available parameters
      info += "\nLength: " + element.GetParameter("Length")
      info += "\nVolume: " + element.GetParameter("Volume")
      info += "\nElevation: " + element.GetParameter("Elevation")

      Display a message box with the element's parameter information
      DisplayMessageBox(info, "Element Parameters")

    Return Result.Succeeded
```

The secondary development of Revit can be achieved by running the program described. Through the family parameter management function of the product information integration platform, project family statistics and component parameters can be obtained. This functionality supports project managers in querying visual design information efficiently. Statistics of family files and family types within Revit project files can be quickly accessed, as illustrated in **Figure 6**. By selecting a component, the design information of key elements such as walls, slabs, beams, and columns can be retrieved promptly, as shown in **Figure 7**. Furthermore, additional design information can be integrated through the extension of family parameters [24].

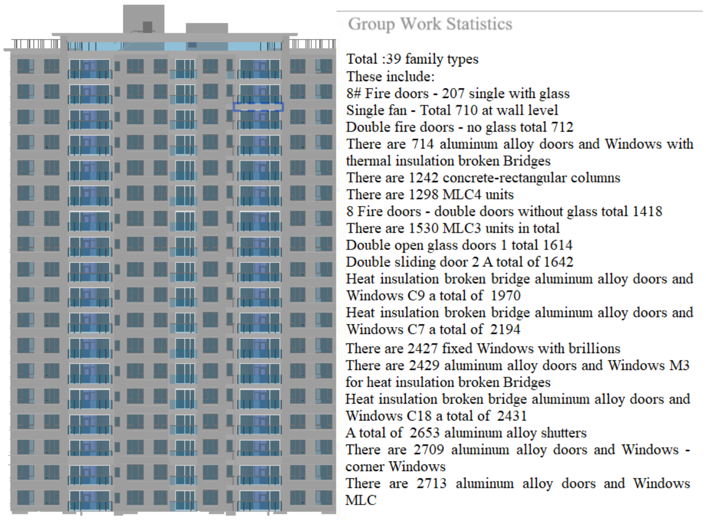

Figure 6. Statistical results of the item families

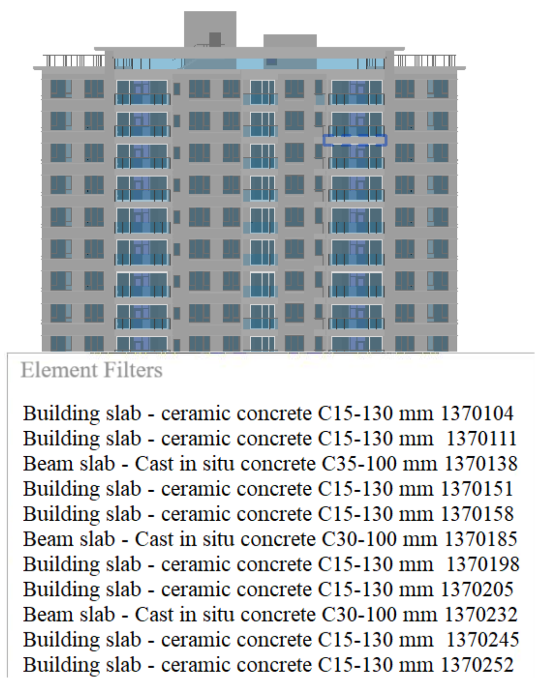

Figure 7. The element information obtained from the element filter

3. Project data management — relational database

The foundation of any information management system and platform is the database, serving as a crucial data repository. Key relational databases today include MySQL, SQL Server, and distributed databases. The prefabricated building project supply chain information integration management platform gathers data from two main sources: structured BIM model information and extensive semi-structured or unstructured data generated during construction [25]. This necessitates the establishment of both a BIM database and an SQL database.

Using BIM model outputs as a foundation and integrating them with SQL Server, the platform consolidates various extended construction-phase information to create a comprehensive data source for project information management [26]. This data source not only underpins the information integration management platform but also supports the development of integrated BIM models [27]. The interaction between the database and Revit involves five key steps, as illustrated in **Figure 8**.

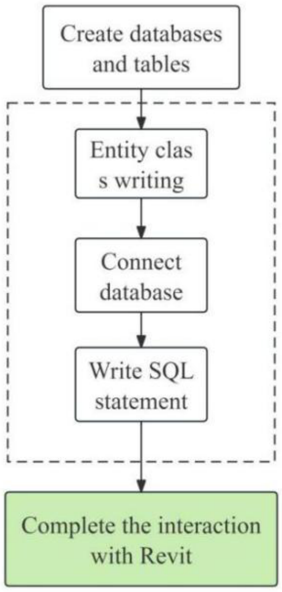

Figure 8. The interaction process

Post-database construction, data sharing and exchange between application software and the database are crucial. Revit's ODBC (Open Database Connectivity) facilitates seamless connections to database management systems. ODBC enables systematic reading and writing of extensive BIM database information, achieving data exchange and sharing [28]. The database framework for the prefabricated building project supply chain information integration management platform, based on BIM, is depicted in **Figure 9**.

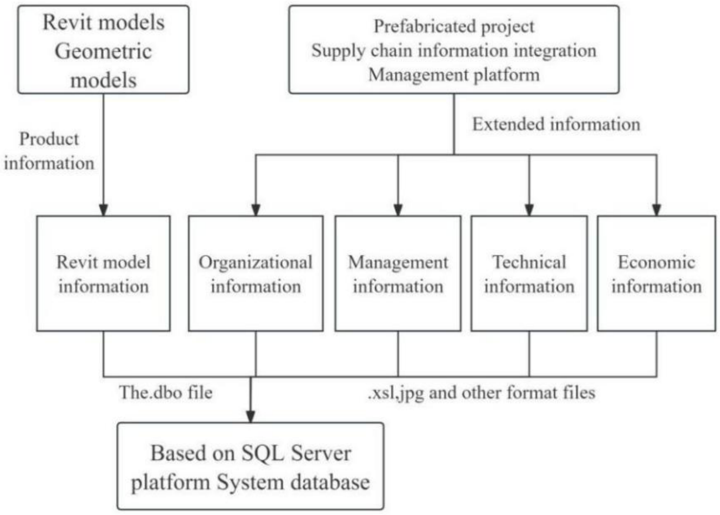

Figure 9. Database construction of project information integration

4. Management platform

4.1. Web platform interface development

To ensure efficient access and utilization of project information, an effective information management system is crucial for seamless sharing and circulation. In web application development, we primarily employ ASP.NET, JSP, and PHP technologies. ASP.NET, a component of Microsoft's .NET framework, facilitates the creation of dynamic, interactive web pages capable of database interaction and personalized content display based on access time and user needs [29]. Its strengths lie in multi-browser compatibility and support for multi-tier development models, which separate logical code into distinct files, thereby clarifying project structure and simplifying later management and maintenance.

This paper proposes a web platform for integrated management of prefabricated building project supply chain information, leveraging the ASP.NET framework. The system architecture is illustrated in **Figure 10**.

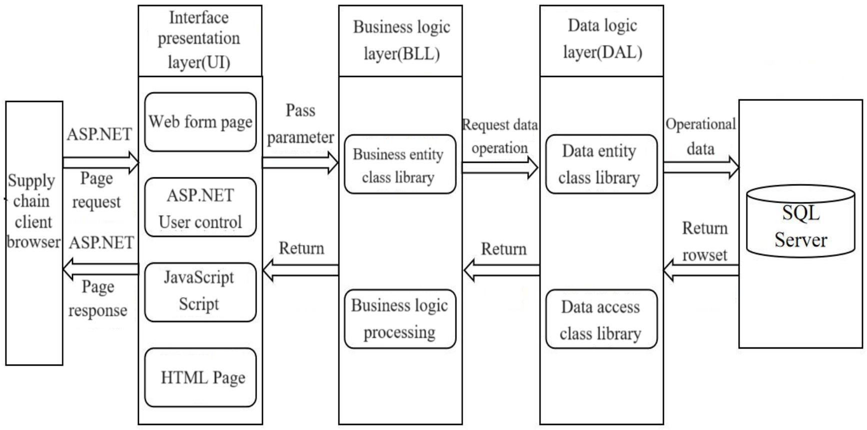

Figure 10. System architecture diagram of the informationintegration management platform

The platform employs a three-layer architecture: the User Interface (UI), Business Logic Layer (BLL), and Data Access Layer (DAL). The DAL handles database interactions, ensuring the BLL accesses necessary data through queries and updates. The BLL processes business logic, performs computations, and validates data, guaranteeing accuracy and integrity, then returns results to the UI [30]. The UI focuses on intuitive design and functionality for user interaction. This architecture is depicted in **Figure 11**.

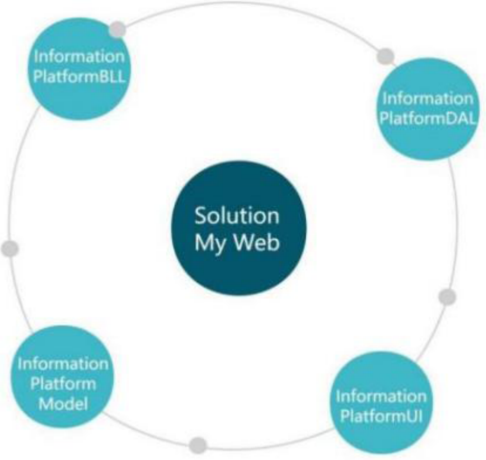

Figure 11. Three-level architecture solution of informationintegration management platform

Figure 12 outlines the technical pathway for integrating supply chain information in prefabricated building projects: Using Revit to build BIM models and integrate product data, enhancing functionality via Revit API for structured information visualization. Leveraging a relational database (e.g., SQL Server) integrates structured and unstructured data. An external database connection facilitates an information management platform, enabling centralized management of project data [31]. All datasets are stored in the relational database, merged with the BIM model for integrated functionality and BIM software applications.

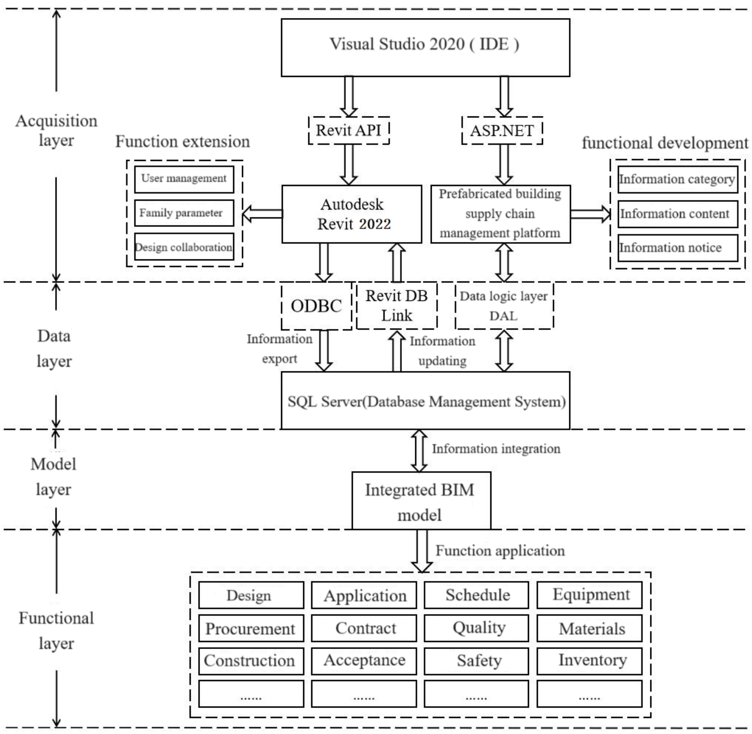

Figure 12. Implementation path of project supply chaininformation integration management technology

5. Conclusion

This article explores the architecture of a BIM-based supply chain information sharing platform for assembly buildings, highlighting its application and value in the industry. Research shows that BIM enhances design efficiency, scheduling, resource optimization, cost control, quality, delivery times, and overall supply chain management in construction. The platform, centered around Revit software, integrates various supply chain information, enabling all participants to access accurate design data for optimized processes. Equipped with data storage, processing, and visualization tools, it aids in managing project uncertainties. This BIM-based architecture introduces an innovative management model, offering significant theoretical and practical benefits.

Currently in the theoretical development stage, the research lacks comprehensive validation. However, future integration of IOT, GIS, VR, and cloud computing promises to enhance supply chain resilience and sustainability, further driving innovation and sustainable development in the construction sector.

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Disclosure statement

The authors declare no conflict of interest.

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