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A Conceptual Framework for Technology Integration in Residential Architecture

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Abstract: Modern residential housing planning faces substantial complexity, spanning regulatory compliance, diverse user preferences, and demands for resource efficiency and sustainability. These challenges are often magnified by insufficient coordination, resulting in inefficiencies and potential errors. Through a purposive literature review, this study addresses a critical gap in the literature regarding conceptual frameworks that integrate architecture and information systems, particularly during the residential planning phase. Information System (IS) integration has become essential, enabling holistic building data management, analysis, and design optimization. Although technologies such as Building Information Modeling (BIM) and Decision Support Systems (DSS) are widely recognized for their potential, existing studies emphasize specific technologies or practical implementations, leaving a need for a more abstract and foundational integrative model. This study develops an innovative conceptual framework model depicting the essential synergy between architectural design principles and information systems capabilities to optimize the planning process. The proposed model positions information systems as the main enabler, supporting data management, analysis, and visualization through an Integrated System that combines BIM, DSS, and the Internet of Things (IoT), producing data-driven, collaborative, and optimized planning outputs. This framework provides a theoretical foundation for future interdisciplinary research in technology-driven residential planning.

Keywords: architecture; BIM; DSS; conceptual; framework



SDGs Problem Solving

This research supports SDGs Chapter #11 by promoting data and technology in housing development. The framework incorporates Building Information Modeling, Decision Support Systems, and the Internet of Things, boosting sustainability, efficiency, collaboration, and resource optimization. These advances help create stronger, more inclusive, and resilient urban environments for the future.

Conflict of Interest Statement: The author(s) declares that the research was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

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1. INTRODUCTION

Residential housing, as a fundamental human need, continues to evolve in design, technology, and management. The modern planning process for residential housing confronts significant challenges, ranging from regulatory complexity and varied user preferences to the need for resource efficiency and sustainability. The lack of effective coordination between design, construction, and post-occupancy management often becomes a major bottleneck, causing inefficiencies and potential errors. This issue can be ameliorated through improved communication and risk reduction facilitated by Information Systems integration (Abdelalim *et al.*, 2024).

In this digital era, modern design-build approaches increasingly rely on technology as an integral aid to manage building data comprehensively, from initial concept to maintenance (Hu and Xu, 2023). Information Systems integrate hardware, software, data, processes, and people to control and streamline information flows to achieve specific goals, thereby reducing errors, redundancy, and delays in design and construction processes. The integration of Information Systems in architectural planning is not only potentially beneficial but necessary to mitigate inefficiencies and mistakes that frequently arise, as well as to visualize, analyze, and optimize building designs and operations more effectively (Naeem, Rana and Nasir, 2023). The use of Decision Support Systems, for instance, can enable more data-driven and predictive decision-making regarding building performance, addressing part of the challenges posed by regulatory complexity and diverse user preferences (Cucuzza *et al.*, 2022).

Although these potentials are clear, there remains a critical gap in the literature regarding a conceptual framework that explicitly focuses on the planning phase of residential housing without requiring direct application deployment. The importance of a conceptual framework to guide research and provide a robust theoretical foundation has been widely emphasized in the Information Systems discipline. However, most existing studies tend to emphasize specific technologies or practical implementations, leaving a need for a more abstract and fundamental integrative model for the residential planning domain.

Previous research has highlighted the role of technologies such as Building Information Modeling (BIM) in improving design efficiency and collaboration. BIM, for example, enables real-time collaboration and interdisciplinary interaction through centralized data, improving project performance and productivity. The Internet of Things IoT has also been explored for residential management, connecting devices for monitoring and application-based management (Ohize *et al.*, 2024; Iqbal and Mirzabeigi, 2025). Critical for decision-making, Decision Support Systems have been shown to assist with analyses of energy and cost efficiency and to streamline construction processes (Kamari *et al.*, 2018).

In strategic information systems planning for the housing sector, Suroso et al. highlight the importance of IS for the management of multi-story housing, underscoring the need for integrated information systems to support governmental housing functions (Suroso, Mauritsius and Setyawan, 2018). Other studies discuss the significance of conceptual frameworks in Information Systems research. Antunes et al. emphasize that conceptual frameworks are essential for communicating research results and helping audiences understand the study focus; they can be viewed as phenomena within research (Antunes, Johnstone and Thuan, 2025). The relevance of conceptual

frameworks also appears in enterprise architecture as a formal, structured way to understand and define an organization.

Research on the integration of information systems and architecture also includes efforts to develop a "dynamic architecture" that bridges the technical representation of information with classical building planning (Gorgorova and Sarkisyants, 2018). Information integration in the context of BIM-GIS is discussed to bring together different models (Beck, Borrmann and Kolbe, 2020). Some studies have also proposed frameworks to align information flows throughout the building lifecycle, such as information flow synchronization frameworks (Beck, Borrmann and Kolbe, 2020), which is relevant for residential planning.

Given these gaps in the literature, there is a clear need for a conceptual framework that transcends specific technology implementations and provides a theoretical foundation for understanding the integration of architecture and information systems in residential planning. Unlike previous frameworks that focus on BIM-GIS integration or dynamic architecture studies for commercial buildings, this research proposes a holistic model specifically designed for the residential planning context, emphasizing the synergistic relationship between architectural principles and IS capabilities from the earliest planning stages.

Therefore, this study aims to fill that gap by (1). Analyzing the fundamental concepts and principles of architecture in residential planning; (2). Examining the essential role and potential of Information Systems as a primary support for architectural planning processes; and (3). Developing an innovative conceptual framework model to cohesively integrate the two disciplines for more adaptable residential planning.

Most of the existing research tends to be oriented towards specific technologies or practical applications. This research aims to fill this gap by developing a more abstract and fundamental conceptual model, as a theoretical foundation for the development of technology or methodology in the future.

2. METHODOLOGY

This study employs a qualitative-conceptual approach using purposive literature review to develop the conceptual framework model. Unlike systematic reviews that aim for exhaustive coverage of all existing studies, this approach focuses on identifying and analyzing key seminal works and recent developments most relevant to architecture-IS integration in residential planning rather than comprehensive empirical aggregation (Ramonell, Chacón and Posada, 2023).

The literature was conducted through a purposive selection process targeting articles that contribute significantly to understanding the integration of Information Systems in architectural planning, particularly for residential contexts. The review spanned publications from 2017 to 2025, prioritizing recent technological developments while including foundational works that establish key theoretical concepts. Literature was identified through multiple academic databases including Scopus, Web of Science, and Google Scholar, using search terms such as "BIM residential," "Decision Support System architecture," "IoT smart home," "information systems planning," and "conceptual framework IS."

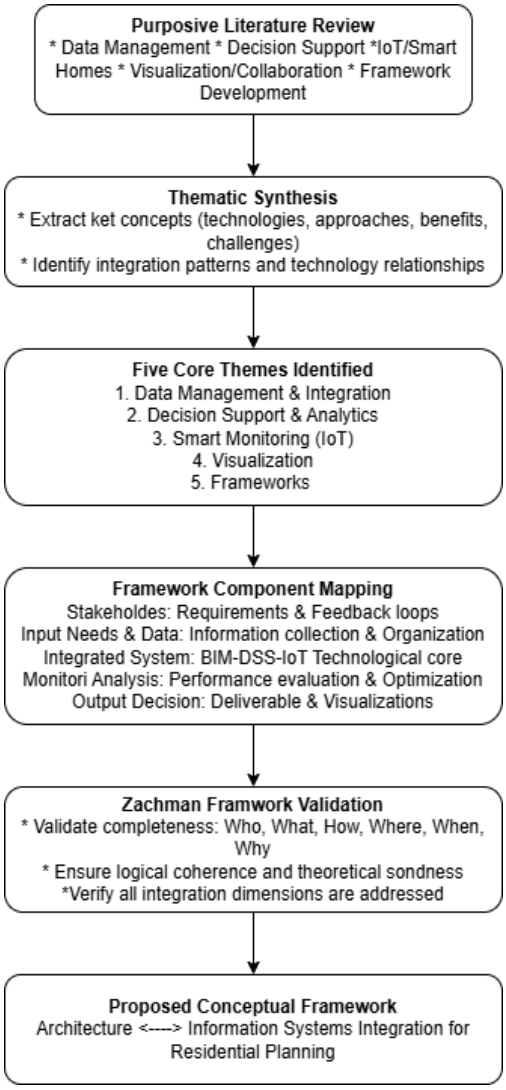


Figure 1. Research flow

Figure 1 shows a step-by-step process for coming up with a suggested conceptual framework that combines architecture and information technology for planning homes. The first step in the research method is a planned review of the literature. At this point, relevant academic articles, technical reports, and industry publications are carefully chosen to focus on certain topics, such as data management, decision support systems, the Internet of Things (IoT) and smart homes, visualization techniques, collaboration mechanisms, and framework development methodologies. The goal of this focused review is to not only describe previous works, but also to critically evaluate and combine knowledge that will directly help in creating an integrated architectural-information systems framework. The study makes sure that the conceptual framework is both relevant and complete by focusing on these specific areas.

After the literature review, the method moves on to topic synthesis. In this stage, important ideas are taken out of the collected material. These ideas include technology, methodological methods, advantages, and known problems. Instead of looking at each study on its own, thematic synthesis groups similar ideas into coherent groups. Building Information Modeling (BIM), Decision Support Systems (DSS), Internet of Things (IoT) sensors, and data analytics platforms are some examples of

technologies that could become important parts. It is also clear that common issues like data interoperability, stakeholder coordination, and system scalability exist. This stage is all about finding patterns of integration and connections between different technologies. Understanding how different systems work together, like how IoT devices send real-time data to analytics platforms that help people make decisions, is important for creating frameworks.

The thematic synthesis finds five main themes: (1) Data Management and Integration, (2) Decision Support and Analytics, (3) Smart Monitoring (IoT), (4) Visualization, and (5) Frameworks. Each topic is a building block of the proposed system. Data Management and Integration focus on gathering, storing, organizing, and making sense of different datasets from architectural models, sensors, and stakeholders. Decision Support and Analytics is all about using analytical models, performance assessment, and prediction tools to turn raw data into useful information. Smart Monitoring (IoT) focuses on using connected devices and sensors to gather real-time information about how a building is working, the state of the environment, and how people are using it. Visualization means making complex data easier to understand and share by displaying it in formats like dashboards, 3D models, and graphical interfaces. The Frameworks theme makes sure that all the parts are put together in a way that makes sense and is based on sound theory.

The framework component mapping phase turns these themes into operational elements after they have been found. This step explains how each theme works within the system architecture. Stakeholders are important people whose needs and input have an impact on how the system is built. Their needs affect how the data is collected, making sure that the system gets the right information about the architecture, the environment, and the users. The core of the integrated system is made up of BIM, DSS, and IoT technologies (Kamari *et al.*, 2018; Beck, Borrmann and Kolbe, 2020; Cucuzza *et al.*, 2022; Abdelalim *et al.*, 2024; Iqbal and Mirzabeigi, 2025). It connects data sources to analytical tools. Monitoring and analytical functions check how well the system is working and help make it better, making sure that it keeps getting better. The final output includes decisions and visualizations that are the system's deliverables. These help planners, architects, and policymakers make smart choices.

The Zachman Framework is used to check the framework's strength. This validation process checks for completeness by answering the basic questions: Who, What, How, Where, When, and Why. These dimensions make sure that all parts of system design are covered, including stakeholders (Who), data items (What), procedures (How), locations (Where), timing (When), and motives (Why). The validation process makes sure that everything makes sense and that the theory is sound. It also checks that integration between architectural and information system domains is complete and consistent. By checking all the integration factors, the research makes the proposed framework more reliable and fills in any gaps in understanding (Nurnaningsih, 2017; Rahayu and Hadiana, 2017).

The result is a proposed conceptual framework that combines architecture and information technology for planning homes. This structure shows how data moves from stakeholder needs to integrate technological systems, how it is processed and analyzed, and how visualization tools help people make informed decisions. It stresses interoperability, ongoing feedback, and performance improvement, which makes sure that it can work in different types of homes. The graphic shows a step-by-step method, from reviewing the literature to creating a validated framework, that makes

sure the proposed solution is both theoretically sound and practically useful for helping people plan their homes in a smart, data-driven way.

2.1. Concepts of Architecture in Residential Planning

Architecture is defined as the discipline that blends art and science in the design and construction of built structures. In the context of housing planning, architecture extends beyond aesthetics to encompass functionality, sustainability, occupant comfort, and harmonious integration with the surrounding environment (Jensen *et al.*, 2018).

The architectural planning process comprises a sequence of stages starting from the formulation of an initial concept, followed by design development, and culminating in technical detailing. Residential architecture also integrates sociodemographic and physical considerations that shape occupants' spatial experiences (Lambrix *et al.*, 2024). Furthermore, architectural choices are often guided by long-term goals and the needs of the organization or individual, including data, application, and information technology dimensions that are well integrated (Nurnaningsih, 2017).

Building Information Modeling BIM, as a digital representation of the physical and functional characteristics of a facility, provides a shared information model to support decision-making throughout the building life cycle (Taherdoost and Madanchian, 2023). BIM also offers benefits such as improved quality, clash detection, enhanced collaboration, and visualization (Naeem, Rana and Nasir, 2023).

2.2. Concepts of Information Systems

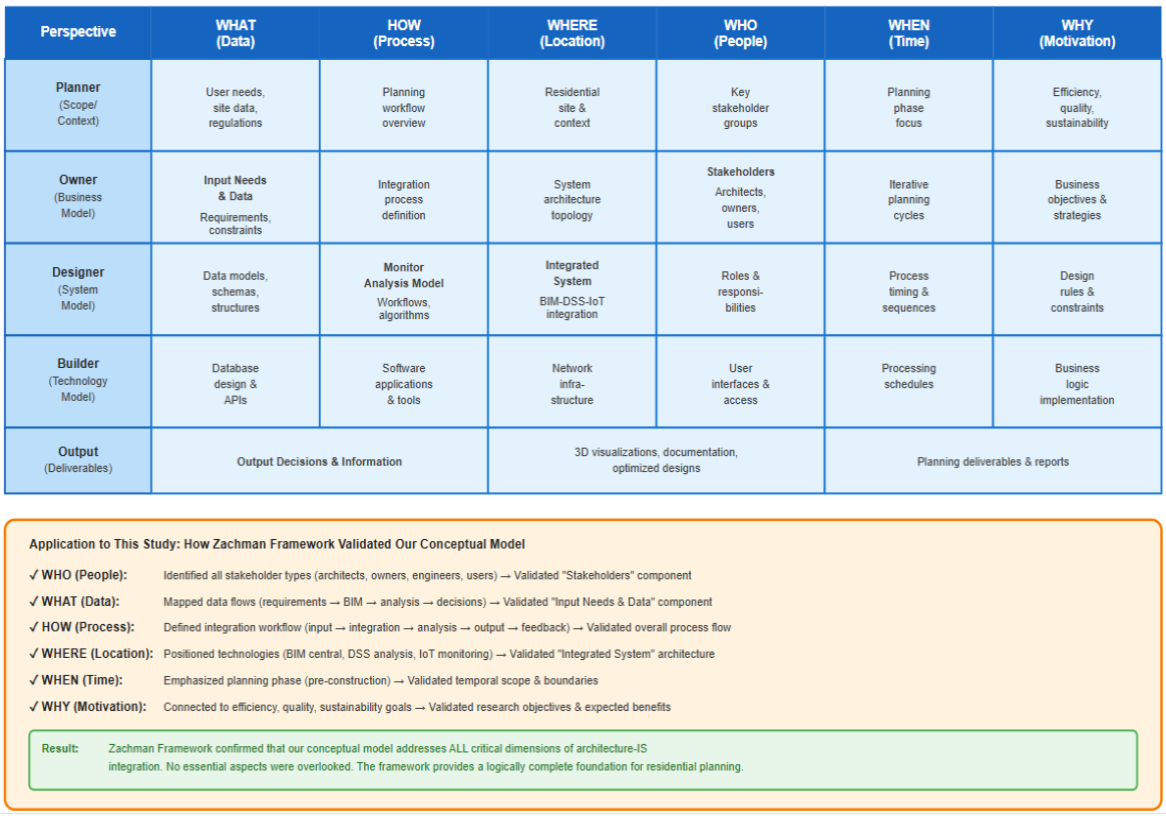
Information Systems are a set of interrelated components that collect, process, store, and distribute information to support decision-making and control within an organization (Adham, 2024). In planning contexts, IS can provide tools to manage data, perform analyses, and facilitate communication. Foundational concepts of data, information, and information systems are essential for effective organizational management and data-driven decision-making (Bidgoli, 2023; Amirullah and Anis, 2025). Internet of Things: This concept enables devices and sensors within a home to connect and share data for smart monitoring and management (Abdelalim *et al.*, 2024). Decision Support Systems: Computer-based systems that assist decision-making by analyzing data and projecting potential outcomes (Cucuzza *et al.*, 2022). Knowledge Graph: Can serve as a primary mechanism for data integration from multiple sources to create digital twins of building assets, enabling efficient contextual data querying and exploration (Ramonell, Chacón and Posada, 2023).

2.3. Integration of Architecture and Information Systems

Integration of architecture and information systems involves merging principles of physical design with data management and analysis capabilities. The overarching goal is to create smarter, more efficient, and responsive planning processes (Masuda and Viswanathan, 2025). Enterprise Architecture Planning can provide a framework for developing comprehensive and integrated information systems (Supriadi and Amalia, 2019). Frameworks such as the Zachman Framework are commonly used in information system architecture design to classify and organize architectural artifacts. The Zachman Framework (see Figure 2) offers a comprehensive structure for identifying

and defining requirements across business, information, application, and technology architectures, which are essential for strategic IS planning (Rahayu and Hadiana, 2017).

The accompanying Figure 2 illustrates a systematic depiction of the Zachman Framework modified to authenticate a conceptual model in a research project. The table comprises six columns—What (Data), How (Process), Where (Location), Who (People), When (Time), and Why (Motivation)—and multiple rows reflecting various stakeholder perspectives: Planner (Scope/Contextual), Owner (Business Model), Designer (System Model), Builder (Technology Model), and Output (Detailed Representations). This matrix form guarantees a thorough examination of every essential feature of the system from several perspectives, hence enhancing the validity and completeness of the conceptual model.



Perspective	WHAT (Data)	HOW (Process)	WHERE (Location)	WHO (People)	WHEN (Time)	WHY (Motivation)
Planner (Scope/ Context)	User needs, site data, regulations	Planning workflow overview	Residential site & context	Key stakeholder groups	Planning phase focus	Efficiency, quality, sustainability
Owner (Business Model)	**Input Needs & Data** Requirements, constraints	Integration process definition	System architecture topology	**Stakeholders** Architects, owners, users	Iterative planning cycles	Business objectives & strategies
Designer (System Model)	Data models, schemas, structures	**Monitor Analysis Model** Workflows, algorithms	**Integrated System** BIM-DSS-IoT integration	Roles & responsi-bilities	Process timing & sequences	Design rules & constraints
Builder (Technology Model)	Database design & APIs	Software applications & tools	Network infra-structure	User interfaces & access	Processing schedules	Business logic implementation
Output (Deliverables)	**Output Decisions & Information**		3D visualizations, documentation, optimized designs		Planning deliverables & reports	

Figure 2. Zachman framework applied to architecture-IS integrations

The Planner viewpoint emphasizes on the whole extent of the system. This entails recognizing fundamental data entities and overarching data needs under the What (Data) column. These constitute the essential information entities that the system must manage. In the How (Process) column, the planner delineates important business processes or strategic workflows that articulate the system's macro-level operation. The Where (Location) column pertains to the geographical or network distribution of operations, specifying the locations of system components or activities. The Who (People) column delineates major stakeholders, such administrators, managers, or end users, who engage with the system. The When (Time) column delineates significant events, cycles, or planning horizons, whereas the Why (Motivation) column elucidates the enterprise's goal, vision,

and strategic objectives. This framework guarantees that the conceptual model is congruent with organizational objectives and contextual limitations.

Transitioning to the Owner viewpoint (Business Model), the framework gets more intricate and functional. The What column delineates certain business requirements and data definitions to enhance clarity concerning information demands. The How column provides a detailed explanation of business process concepts, outlining workflows and functional relationships comprehensively. The Where column delineates the system architecture concerning business locations or operational settings. Under Whom, distinct organizational roles and tasks are delineated, elucidating accountability. The When column delineates business cycles, timetables, or temporal limitations that regulate activities. Ultimately, the Why column clarifies corporate objectives and performance benchmarks. This viewpoint guarantees that the conceptual model precisely represents actual company activities and user anticipations.

The Designer viewpoint (System Model) converts business needs into technical system specifications. In the What column, data models, schemas, and structures are defined to delineate the logical organization of information. The How column delineates application functionalities, algorithms, and process models that execute business operations. The Where column delineates system architectural design, encompassing distributed system setups or deployment diagrams. The Who column delineates system responsibilities and access rights, guaranteeing suitable user interaction and security management. The When column pertains to process timing and sequencing logic, including event triggers and transaction flows. The Why column delineates design limitations and performance standards. This level guarantees that the conceptual model is technically viable and logically coherent.

From the Builder viewpoint (Technology Model), the system is converted into tangible implementation components. The What column delineates database tables, data storage methods, and physical data types. The How column delineates software modules, code architectures, and executable procedures. The Where column delineates network architecture, hardware infrastructure, and server settings. The Who column delineates user interfaces and access control systems. The When column specifies real scheduling techniques, batch tasks, or runtime processes. The Why column guarantees that implementation decisions are consistent with operational objectives and compliance standards. This phase verifies that the conceptual model can be feasibly executed using existing technology.

The Output row signifies the ultimate deliverables of the framework application. These encompass recorded system models, verified architectural designs, and strategic planning papers. The output integrates choices and information from all viewpoints, guaranteeing traceability from strategic goals to technical execution. The approach ensures thorough coverage and reduces gaps or inconsistencies by documenting outcomes at every intersection of viewpoint and abstraction.

The lower half of the picture elucidates the application of the Zachman Framework in validating the conceptual model of the study. Each column underwent a methodical assessment: What (Data) ensured the identification of all requisite data entities and attributes; How (Process) validated workflows and operational protocols; Where (Location) affirmed alignment with system architecture; Who (People) authenticated user roles and stakeholder responsibilities; When (Time)

addressed temporal dependencies and scheduling factors; and Why (Motivation) ensured congruence with organizational objectives and anticipated benefits. The findings demonstrate that the conceptual model was rigorously evaluated and confirmed across all six dimensions, guaranteeing structural integrity and logical consistency.

Integration can take various forms:

a. Centralized data management: An IS serves as a central repository for all data related to the architectural project, from client requirements to material specifications, reducing data fragmentation.
b. Data-driven analysis: An IS enables performance analyses, cost evaluations, and comprehensive environmental impact simulations during the design phase.
c. Enhanced collaboration: An IS platform facilitates real-time collaboration among diverse stakeholders.
d. Evidence-based decision-making: Systematized data and analyses support planning decisions based on empirical evidence beyond intuition.

2.4. Conceptual Framework

A conceptual framework is a structure that helps organize ideas and concepts to achieve a research objective. In this study, the conceptual framework will function as a blueprint for understanding how architecture and information systems can interact synergistically in residential planning. It outlines the main components and the relationships among them, providing a holistic view of the integration process. Conceptual frameworks are important for communicating research and focusing attention on what is within the frame, while acknowledging limitations outside the frame

3. RESULTS AND DISCUSSION

The proposed conceptual framework model depicts the synergy between architectural design principles and information systems capabilities to optimize the planning process for residential housing. The model comprises several interrelated components.

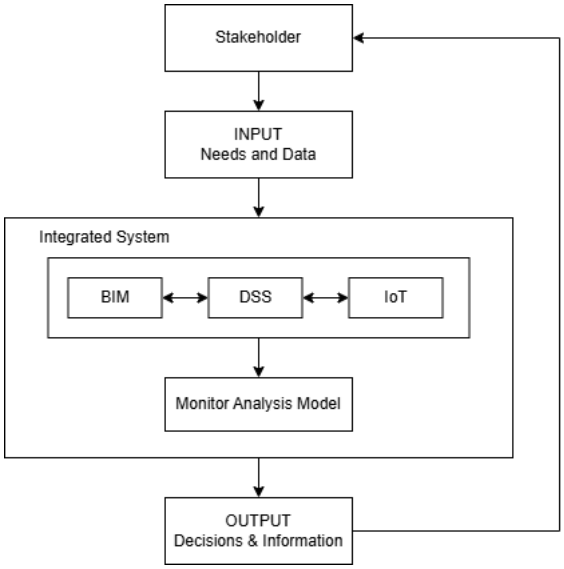


Figure 3. Conceptual framework model for the integration of architecture and information systems

The framework (see Figure 3) presents an end-to-end information-based planning workflow for residential planning. It emphasizes an adaptive feedback cycle among stakeholders, the integrated system, and planning outcomes:

1). Stakeholders: The starting and ending point of the process, comprising individuals or entities whose needs must be accommodated (for example, Architects, Owners, Engineers, Contractors).

2). Input Needs and Data: All initial information required for planning, including user preferences, regulations, and geospatial data. The information system components ensure this input data are collected and managed comprehensively.

3). Integrated System: The core where architecture and information systems integrate. This system consists of interdependent modules: a. BIM Building Information Modeling: Provides a shared information model, enhancing quality and interdisciplinary collaboration. b. DSS Decision Support System: Aids data-driven and predictive decision-making, such as energy and cost efficiency analyses. c. IoT Internet of Things: Enables connected devices for smart monitoring and management, whose data can be repurposed for future planning.

4). Monitor Analysis Model: After data processing by the integrated system, this phase involves building performance analysis (for example, energy efficiency, lighting, and airflow simulations) and the use of algorithms to identify optimal design solutions.

5). Output Decisions & Information: The results of the integration process, including more informed planning decisions, immersive 3D visualizations, and optimized documentation. These outputs are fed back to the stakeholders for evaluation, creating an adaptive planning cycle.

Overall, the model demonstrates that residential planning benefits from a diverse planning mindset as input. The Information System components function as the primary enabler supporting the Architecture components at every stage of the integration process. For example, the IS can assist with Data Management for functional and sustainability criteria, perform Data Analytics to optimize designs, and provide enhanced visualizations for design concepts. The outcome of the integration is a more informed and optimized planning output.

Integration of residential planning through technology enables comprehensive collection and management of input data—from geospatial information to user preferences—supporting efficient data storage, access, and analysis as a basis for data-driven management (see Figure 4). With IS support, architects can enhance design capabilities through performance simulations (energy efficiency, natural lighting, and airflow) and the use of algorithms and data analyses to identify optimal design solutions. IS also yields immersive 3D visualizations that help clients and stakeholders understand the design and improve the quality of presentations and documentation.

Information Systems play a central role not only as an aid but as the core of the integration process. This includes centralized data management to reduce information fragmentation, decision support through DSS to analyze design alternatives and their impacts, real-time collaboration that improves communication and reduces project conflicts, and data interoperability via knowledge graphs or semantic web technologies to integrate diverse sources.

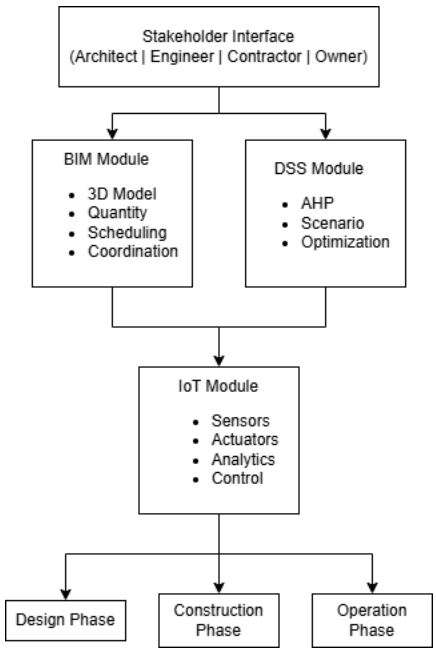


Figure 4. BIM-DSS-IoT integration for residential planning

The conceptual model provides a framework for researchers to further explore architecture–IS integration and for practitioners to adopt information-driven approaches in planning. It aligns with the notion of dynamic architecture that bridges technical information representations with building planning, with the expectation of identifying areas where information systems provide maximum value without directly pursuing complex application development. However, this conceptual model has limitations due to its abstract nature and lack of empirical validation.

While this conceptual framework offers significant potential for residential planning, several challenges must be acknowledged. Data privacy and security remain critical concerns, particularly when IoT devices collect real-time occupant data. Interoperability between different systems (BIM, DSS, IoT platforms) requires standardized data formats and protocols (see Figure 4). Training and change management are essential, as architects and planners must develop new competencies in data analytics and information systems. Additionally, initial implementation costs may present barriers for smaller firms. This conceptual model is intended as a theoretical foundation to guide future implementation studies and provide a basis for evaluating specific technology deployments in residential planning contexts.

4. CONCLUSION

This study presents a conceptual framework integrating architecture and Information Systems for residential planning, demonstrating that modern housing requires synergy between architectural design principles and IS capabilities in data management and analysis. The proposed model positions Information Systems as the core enabler—supporting centralized data management, evidence-based decision-making through DSS, and real-time collaboration—rather than merely a supporting tool.

Theoretically, this framework provides a foundation for interdisciplinary research at the intersection of architecture and information systems. Practically, it guides architects and IS practitioners toward

integrated approaches from the planning phase. The framework's abstract nature, while enabling broad applicability, represents a limitation due to lack of empirical validation. Future research should focus on empirical validation through expert interviews, surveys, and prototype development. This study provides a structured pathway toward data-driven, technology-integrated residential architecture.

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