



PLANNING MALAYSIA:

Journal of the Malaysian Institute of Planners

VOLUME 24 ISSUE 2 (2026), Page 582 – 610

BUILDING TO CITY: INTEGRATING BIM INTO CIM FOR A COMPREHENSIVE DIGITAL URBANISM

Mohammed Faisal Ghazi AL Kazee¹, Islam Sallam^{2*}

*^{1,2}Department of Architecture and Interior Design,
UNIVERSITY OF NIZWA, SULTANATE OF OMAN
(Corresponding Author: isallam@unizwa.edu.om)*

Abstract

The transformation from Building Information Modeling (BIM) to City Information Modeling (CIM) poses a major challenge for achieving holistic digital urbanism. While BIM delivers object-based, detailed models of individual structures, scalability and semantic structure always fail when multiplied and transferred in scale and complexity for urban systems. This paper addresses BIM integration in CIM for the construction of a multi-scale, semantically interoperable urban digital twin platform. In a comparative analysis of early pioneers of digital twins – namely Virtual Singapore, Helsinki 3D City and Dubai Digital Twin – our research identifies best practices and common pitfalls related to data standardization, semantic mismatches and computational scalability. Considerable attention has been given to semantic interoperability as a crucial condition for effective data translation at different scaled levels from micro (building scale) to macro (city scale) models. The paper derives a BIM-to-CIM integration framework based on case-based Modeling that demonstrates how individual BIM models constructively inform broader-based CIM platforms for long-term sustainable district planning and management. The resulting framework facilitates robust data-driven urban planning and unlocks interoperability between separate modeling spaces, establishing a stable foundation for potential smart city use cases.

Keywords: Building Information Modeling (BIM), City Information Modeling (CIM), Digital Urbanism, Urban Digital Twins, Semantic Interoperability, Multi-scale Modeling, Smart Cities

² Corresponding author. Email: isallam@unizwa.edu.om

INTRODUCTION

Rapid advances in digital technologies have changed the face of planning, managing and experiencing cities. With increasing complexity in urban environments, there has also been a related need for holistic, data-driven solutions. [1] Digital urbanism - a conceptual solution that uses digital instruments and data infrastructures for urban governance, sustainability and resilience - becomes a very appealing solution. Central to this revolution is the digital twin: a real-time, virtual model of a physical resource or system that enables real-time monitoring, simulation and informed decision-making. Building information Modeling (BIM) has long formed the basis for digital models at the building level, and has provided detailed, semantically enriched models of individual buildings. [1] However, its application is limited essentially to stand-alone assets, and consequently, its usefulness in addressing the interrelated systems that characterize cities is limited. City Information Modelling (CIM), by contrast, aims at modelling complete urban fabrics by integrating disparate sources of data in support of large-scale planning of infrastructures, environmental monitoring, and policymaking. Although related by shared precepts, BIM and CIM operate at different levels of scale and of vocabulary and consequently pose serious barriers to interoperability. [2]

This paper addresses the critical task of filling the micro-to-macro scale gap between BIM and CIM. Specifically, it discusses how BIM approaches can be integrated into CIM systems for enabling multi-scale, semantically interoperable urban digital twins. To facilitate interdisciplinary comprehension, two of the essential concepts of this research are explained. Semantic interoperability is defined as having the capacity of various digital systems and data models to share information and maintain its meaning, context and relationships. [3] Semantic interoperability within BIM and CIM integration means that information at the building level, comprising of components, spatial relationships and infrastructure systems can be properly interpreted upon transfer to the urban scale modelling environment. [4] In the absence of semantic interoperability, the data that is streamed between BIM and CIM systems can lose its meaning or end up being inconsistent because the modelling standards of the systems, including Industry Foundation Classes (IFC) and City GML, differ.

The other important term is multi-scale modelling which is defined as the process of integrating varying spaces into a single modelling environment. [5] Multi scale modelling allows digital representations to be operated on multiple levels of complexity at the same time, such as the micro level (individual building elements), meso level (district or neighbourhood level), and the macro level (city-wide systems). [6] This top-down solution enables the use of detailed building data produced by BIM to be used elsewhere in the analysis of the urban environment in the wider context of CIM systems so that planners and decision-

makers can relate architectural data to wider planning approaches. The research highlights the requirement for semantic interoperability in enabling smooth data translation from one system and from one scale to another. [7] In a comparative case-based examination of early digital twin applications- Virtual Singapore, Helsinki 3D City, and Dubai Digital Twin- the article reviews dominant practice, technical limitations, and conceptual developments in the literature. Finally, this work proposes a BIM-to-CIM Integration Framework, which permits data-enabled resilient urban planning by enabling an efficient data translation, scaling, and synchronization. By doing this, it offers extensions to the research within the domain of digital urbanism that gives a tangible path of giving more intelligent, integrated, and sustainable cities.

LITERATURE REVIEW

Overview of BIM and CIM Technologies

Building Information Modelling (BIM) has become a foundation practice within the Architecture, Engineering, and Construction (AEC) industry. [8] It makes it possible for highly detailed digital models of built assets that encompass geometry, metadata, and behavioural information from design through construction use and demolition. [9] BIM models enable enhanced collaboration among stakeholders and provide fundamental information regarding cost estimation, clash detection, construction sequences, and energy analysis. Nevertheless, the basic focus resides in individual structures, normally separated from their wider urban context. [10]

Urban Information Modeling (CIM) expands and extends BIM fundamentals for Modeling entire cities. CIM collects geospatial data, sensor data, BIM inputs and environmental models for a regular urban digital ecosystem. [11] It facilitates applications for transportation modelling, flood hazard assessment, energy simulation at the district level, and policy evaluation. CIM has a tendency to utilize Geographic Information Systems (GIS), 3D city models, and semantic modelling conventions like City GML for modelling urban features like roads, buildings, vegetation, and utility networks in a spatially coherent way (Zhang et al., 2020; Yan et al., 2019). While BIM and CIM both strive for digital modelling of physical assets, their scope, structure of data, and contexts of use are very distinct. [12]

Previous Efforts and Integration Frameworks

In recent years, there has been increased activity in linking BIM and CIM based on a need to extend building-scale models towards wider urban applications. Some of the main approaches have involved employing data exchange protocols such as the use of the IFC for BIM and City GML for CIM, frequently involving modified conversion or middleware solutions in order for systems to interoperate. [6] A second exemplary instance is Virtual Singapore, an initiative of national

guidelines that dwells on using BIM, GIS, and live sensor information with the goal of creating a digital reflection of the whole city-state in real-time. The platform is based on semantic 3D models applied in an array of different applications, including urban planning and energy optimization, as well as in the case of disaster response. [13] There is also the case Helsinki 3D City, which combines semantic city models with a reality mesh to model the solar potential, energy consumption and behaviour of pedestrian movement. The project uses open standards and APIs for sharing data and building services. [6]

In the Dubai Digital Twin project, for example, BIM building models are integrated with GIS systems for the creation of real-time operational dashboards and prediction models for urban management. The above examples showcase the potential of BIM-CIM interoperability and also indicate that no common integration framework has yet emerged, preventing replication and scaling for multiple applications. [14]

Principal Barriers: Semantic Interoperability, Data Heterogeneity, and Scaling Limitations

BIM to CIM integration initiatives is confronted with a number of technical and conceptual difficulties, although they seem promising. [15] The greatest barrier is semantic interoperability. The models of BIM structures generally accommodate the application of the IFC schema or proprietary schema that describe a wall, door or other structures, including the HVAC system, utilizing domain-specific metadata. CIM models, however, use alternative schema such as CityGML or INSPIRE, which incorporate more extensive urban features and could be a bit less detailed than BIM. The use of non-unified ontologies and naming models will create challenges in the mapping of the data semantics of one model to another, which prevents automation and data reuse. [8]

Heterogeneity in data also contributes to integration challenges. BIM data is highly organized and highly detailed in 3D geometry and construction attributes, yet they are unlikely to contain georeferencing and contextual data essential to large-scale city-scale modelling. Although there exists elaborative CIM data in matters of space relations and topology, inner building logic, and material-level are not might be taken into consideration. Semantic mediation, ontology alignment, and Linked data technologies can bridge that divide. [13]

Scalability limitations are another important issue. BIM models are computationally intensive, often comprised of millions of polygons and rich parametric data. Combining various BIM models within a CIM platform in a direct way results in loss of performance, influx of data, and a problem of versioning. Multi-resolution modelling techniques and hierarchical abstractions have also been proposed by academics for managing this issue, while standardized solutions are not yet available. [5]

Multi-Scale Digital Twins Concept

Multi-scale digital twins are a strategic advancement for digital modelling that aims at aligning at various levels of space and functionality. The systems are capable of modelling buildings, neighbourhoods, districts, and entire cities in a nested and interoperable hierarchy, enabling more holistic decision-making and planning. Leaders among technology companies and research institutions are spending heavily to develop multi-scale digital twins. *Dassault Systèmes* (a French multinational software company that provides businesses with a 3DEXPERIENCE platform for designing, simulating, manufacturing, and managing the lifecycle of products) Virtual Twin Experiences utilize building sensor inputs, BIM, and urban platforms for building predictive analytics and lifecycle insights. Autodesk (2021) views future cities as digital ecosystems in which each asset will be connected to its digital twin for continuous feedback and adaptation. Research and EU-funded programs like SPHERE and FIWARE advocate open semantic models, cloud infrastructures, and Internet of Things (IoT) real-time integration for the purpose of scalability and open-mindedness. [10] All these initiatives are gradually creating a future for BIM and CIM living side by side in shared urban digital twins. Nonetheless, their implementation also needs strong data governance frameworks, real-time synchronizations, and long-term interoperability. [15]

Data Governance, Privacy, and Ethical Considerations in Urban Digital Twins

With the growing use of digital twin technologies in cities, the issue of data governance has become a significant concern to the long-term sustainability and reliability of digital urban systems. Digital twins are based on large datasets, which are based on buildings, infrastructure network, environmental sensors, and even human activity patterns. [3] Therefore, the problem of data ownership, the privacy protection, cybersecurity, and ethical use of data should be considered in the context of BIM-CIM integrations. [13]

A significant issue is related to the incorporation of detailed BIM data into the city-scale digital platforms. Model construction can include sensitive data regarding structure systems, security infrastructure or operational data. Such information, when combined in CIM environments, can pose a possible risk unless there is a clear definition of governance policies. To this end, federated data architecture is frequently adopted by many cities implementing digital twins, in which individual datasets are under the control of their original owners but are connected by standardized interfaces. [12]

The other matter of concern is data privacy especially when the urban digital twins are linked to real-time sensor systems or Internet of Things (IoT) devices which collect and send vast amounts of data on the urban environment continuously. These systems can gather data on mobility, environmental, or

occupancy rates of buildings. Such data streams can be ethically questionable in terms of surveillance and the privacy of citizens without proper protection. [16]

Another important governance issue is cybersecurity. Since urban digital twins are often used as decision support systems in infrastructure management, any security risk in the data platform can have an impact on important city services. [17] Therefore, strong governance systems should include data encryption, access control systems and secure cloud systems. Thus, the successful integration of BIM-CIM is not only a technical problem, but also an institutional and ethical problem. The creation of clear governance structures, guidelines for data ownership and privacy systems is necessary to make digital city twins reliable, secure and socially responsible urban planning instruments. [18]

METHODOLOGY

The study adopts a qualitative, case study method in the examination of the adoption of Building Information Modelling (BIM) into City Information Modelling (CIM) in the field of digital urbanism. It is fundamentally aimed at investigating the scalability of BIM data and processes and semantically transforming them in order to populate the CIM platforms and create multi-scale, interoperable urban digital twins in the future.

Comparative Case Study Method

Methodological foundations of the study are a case study comparative analysis of the following three worldwide digital twin projects:

1. Virtual Singapore [19]
2. Helsinki 3D [6]
3. Dubai Digital Twin [14]

These examples were selected due to the advanced utilization of the urban digital twin and due to the obvious adoption or incorporation of BIM and CIM components. Each is a varied approach to digital urbanism that is informed by the local government, the state of technology infrastructure and policy objectives. The comparative study will analyse the following dimensions:

- Urban-scale planning and the role of BIM models
- Methods of data translation and semantic integration
- Mechanisms of interoperability (standards, “ontology” set of concepts and categories in a subject area or domain that shows their properties and the relations between them.)
- Backend supporting data scalability
- Applications in sustainability, mobility and resilience

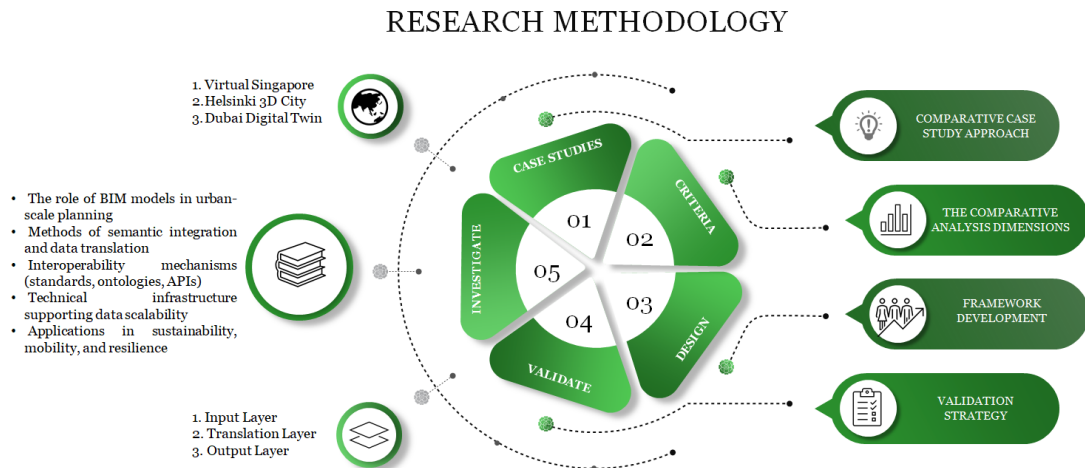


Figure 1: Research Methodology adopted, adapted and developed based on the works of the following references [6] [14] [10] [13]. (The illustrated model is by author)

Comparison of Digital Twin Case Studies

To better understand the operational differences between existing urban digital twin initiatives, the chosen case studies were contrasted in a number of major aspects, such as technological infrastructure, data integration approaches, governance models, and real-world applications. The key features of each initiative are summarized in Table 1.

This comparison highlights that although these initiatives demonstrate the feasibility of BIM-CIM integration, they also reveal persistent challenges related to semantic alignment, data governance, and scalability.

Table 1: Comparative Analysis of International Digital Twin Initiatives and Their BIM–CIM Integration Approaches

Project	Main Objective	BIM–CIM Integration Approach	Key Strengths	Key Challenges
Virtual Singapore	National digital twin platform supporting urban planning, environmental simulation, and infrastructure management	Integration of BIM models with GIS data and sensor networks within a semantic 3D city model	Highly detailed 3D urban model with strong simulation capabilities	Complex governance requirements and data privacy considerations
Helsinki 3D City	Open digital twin supporting energy	Use of CityGML semantic models	Open data ecosystem	Challenges related to maintaining

Project	Main Objective	BIM–CIM Integration Approach	Key Strengths	Key Challenges
Dubai Digital Twin	analysis, solar potential studies, and urban planning	integrated with BIM-derived datasets and open APIs	enabling public access and innovation	semantic consistency between datasets
	Smart city operational platform supporting urban management and predictive analytics	Integration of BIM models with GIS platforms and real-time data dashboards	Strong governmental coordination and operational decision support	Interoperability challenges between different modelling standards

Framework Development

The outcomes of the case studies will inform the development of a BIM-to-CIM Integration Framework that will be the central study deliverable. The framework will be customized to:

- Support semantic interoperability through ontology mapping (for instance, IFC and CityGML schema matching)
- Support multi-scale data modelling of buildings, districts and city systems
- Allow modular integration of BIM data with CIM systems through abstraction and generalization
- Apply hierarchical modelling and reuse of cases for scalable efficiency

The framework will be based on using a *Three-Tier Architecture*: [16]

1. **Input layer:** Procurement of BIM data (geometry, attributes, time series)
2. **Translation:** Semantic mediation through mapping tools, ontologies and transformation scripts
3. **Output Layer:** Integration in CIM systems for planning, simulation, or public dashboard applications

Validation Strategy

Although the framework will initially remain conceptual, the validity will be assessed through systematic comparison with both existing technologies and practical workflows observed in the three study cases, as well as against the proposed theoretical model. Validation will be performed through a combination of empirical testing, cross reference with established standards and expert review.

To ensure robustness, actual standards and tools (e.g. FME, BIMSERVER, 3DCITEDB, CITYGML ADES) will be used where possible, so that the framework can be demonstrated in practice instead of remaining exclusively at a conceptual level. These tools provide practical mechanisms for interoperability testing, data transformation and semantic adjustment, and will thus act as benchmarks that the proposed framework can be evaluated.

In addition, the validation process will involve triangulation of several data sources. Input will be taken from scientific literature, technical white papers and authoritative reports, as well as publicly available data sets for the selected cities. This multi-source method will provide the opportunity to assess both technical health and usefulness in the real world, which ensures that the framework is not only theoretically coherent, but also operational in practice.

Furthermore, validation will include a critical review of how well the framework supports interoperability tasks across scales-from micro level to building components in BIM to the macro level of urban systems in CIM. Performance criteria such as semantic adjustment accuracy, minimization of data loss and easy integration will be used as important indicators of success.

Finally, engagement with domain experts, including practitioners from architecture, engineering science, GIS and urban planning, will form an integral part of the validation strategy. Their feedback will be used to limit the frame, address potential holes and strengthen the adaptability of different urban contexts.

Tool-based experiments, literature-operated verification, by combining testing in the real world, the functioning ensures a comprehensive evaluation of structure strength, reliability and utility for future BIM-to-CIM integration initiative.

SEMANTIC INTEROPERABILITY CHALLENGES AND STRATEGIES

Semantic interoperability is one of the essential needs of integrating BIM seamlessly into systems that support CIM. This ensures that the semantics of the exchanged information remain intact and are understood correctly across different domains, platforms and scales. [20] Nevertheless, this form of interoperability is exceptionally difficult to achieve due to nonconformities in data structures, modeling conventions, vocabulary and ontologies used in both BIM and CIM environments.

Divergent Standards and Ontologies in Smart City Concepts: Integrating BIM, CIM, and GIS

A main barrier to semantic interoperability between Building Information Modelling (BIM) and City Information Modelling (CIM) is that the standards and ontologies supporting each application are mismatched. BIM and CIM were developed with very different purposes and scopes in mind, to incorporate differing data models, classification systems, and conceptual models. For this reason, information exchange and communication between the two is inherently problematic.

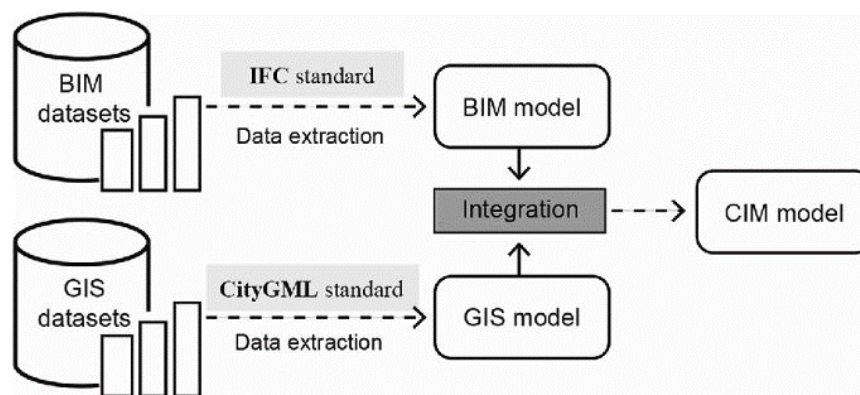


Figure 2: BIM, CIM and GIS interrelationship. [21]

The integration of building information modelling (BIM) and city Information Modelling (CIM) represents a significant step towards the realization of urban digital twins. [5] While BIM is focused on fine-grain models of single buildings, their fit-out, and their infrastructural services, CIM works at the city scale, modelling broader spatial, environmental, and infrastructural systems. Geographic Information Systems (GIS) then supply the critical connection between these two areas through the provision of the spatial referencing, topological relation, and integration of geospatial data that are needed to site BIM information in city-wide models. Through GIS systems, information at the building level can ideally be situated, analyzed, and represented in the wider urban environment, enabling cross-domain interoperability, spatial analysis, and decision-taking. GIS thus not only bridges the semantic as well as the geometric gap between BIM and CIM but also provides the underpinning platform for large-scale, multi-level urban information systems. BIM systems are predominantly founded upon the Industry Foundation Classes (IFC), open, vendor-neutral, standardized data models developed by building SMART International. IFC is designed to provide rich digital copies of constructed entities at the building or component level, with rich geometrical definitions, hierarchical organization of

objects, and long lists of properties such as materials, performance indicators, as well as operating information. [22] It is particularly tailored to address the needs of stakeholders in the Architecture, Engineering, and Construction (AEC) industry throughout the asset's entire lifespan from construction and building designs to operation and maintenance. For comparison, CIM relies on geospatial standards such as *CityGML*, INSPIRE, and LandInfra that are developed and maintained by organizations such as the Open Geospatial Consortium (OGC). *CityGML* is in particular a semantic and geometric 3D city model that represents urban features such as buildings, terrain, water bodies, transport systems, and vegetation. Though very granular like IFC, *CityGML* represents its instances in various Levels of Detail (LoD)—LoD0 (2D footprints) to LoD4 (building interior detail)—so that it can encompass the entire breadth of urban planning and environment analysis use cases. [20]

These two standards, IFC and *CityGML*, not only are structurally distinct but are ontologically incommensurable. For example, while both are capable of representing a “building,” their definition, classification, as well as relation between building subcomponents and subcomponents, differ extensively. [3] While an *IfcWall* in IFC may have thermal resistance or fire rating as parameters, *CityGML Wall Surface* may have orientation or surface material as parameters to capture for environment modeling. Without any ontology or mapping between them, these semantically similar entities cannot automatically be put in alignment, therefore leading to their duplication, misinterpretation, or loss in translation. [3] What contributes to the confusion is that each standard is domain-specific, designed for particular use cases. Construction logic and exact building component behavior are optimized in IFC, while spatial coherence, urban topologies, and GIS platform integration are optimized in *CityGML*. What this implies is not only that information is structured differently, according to standard, but that querying, visualization, and analysis are all affected as well. BIM environments, for instance, support object-based navigation in building hierarchies (e.g., storeys, spaces, systems), while CIM environments are concerned with spatial relations and topological connectivity (e.g., adjacency, containment, routing). [4]

Moreover, the software environments that form the basis for each standard evolved separately. Construction detailing/design-focused BIM software such as Autodesk Revit, *ArchiCAD*, or *Tekla* contrasts with large-scale visualization as well as geospatial modeling-focused CIM software like Esri *CityEngine*, Bentley *OpenCities*, or 3DCityDB. This separatism extends the semantic gap since even well-crafted models do not integrate when transplanted from one platform to another. There have also been efforts to bridge this gap in the form of technologies such as *GeoBIM*, which attempts to integrate IFC and *CityGML* by ontology intermediates or by enriching one model with the other's functionalities. These technologies are still technically composed and not yet

much standardized or distributed. Without ontology adjustment methodologies or formal semantic mapping frames, the majority of BIM-to-CIM data transfers remain limited to manual conversion or case-centric intermediate production solutions. [23]

Divergent standards and ontologies used in BIM and CIM are the primary obstacles to achieving semantic interoperability. Differences in purpose, structure, and semantics between them are in conflict with technical conversion requirements and instead evoke needs for conceptual alignment. Filling this gap is essential in enabling scalable, multi-domain digital twins that can encompass the breadth of single buildings as easily as the scope of entire cities.

Data Abstraction and Level of Detail (LoD)

One of the most important challenges of bridging BIM and CIM is to handle the level of detail (LOD) between the two worlds. BIM environments are intended to host very detailed models of architectural, structural and system components - down to specifications such as bolts, channels or glass finish. This level of precision is necessary for tasks such as construction coordination, amount of start and construction management. As a result, BIM models are generally dense, both in geometry and semantics, and are optimized for the use of microscale. [22]

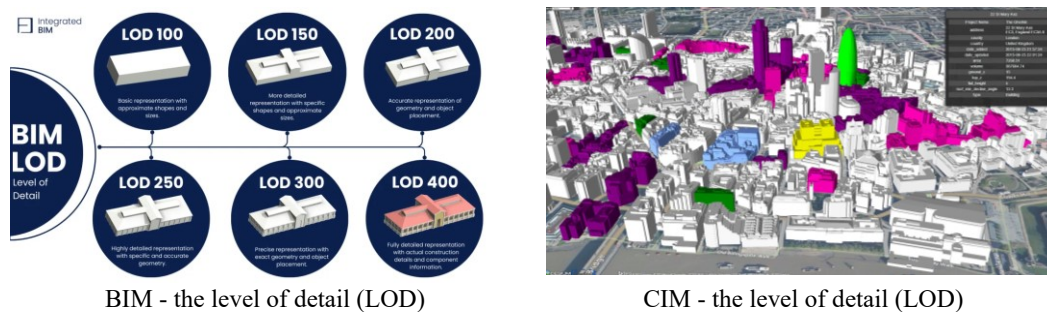


Figure 3: The concept of Level of Detail (LoD) in BIM and CIM represents entirely different modelling priorities: detail and construction in BIM and space abstraction and scalability in CIM, which is a major challenge towards the smooth integration of data.

On the other hand, CIM frameworks are designed for macroscale city analysis. These operate in larger geographical scales and typically generalize urban functions to ensure calculation efficiency and ease of use in high-level planning, environmental assessments and urban-wide infrastructure simulations. For example, CityGML defines several lots (from Lod0 to Lod4) to represent urban objects such as buildings, terrain and vegetation, each with different degrees of details. However, even the most detailed CityGML models rarely reach the specificity of BIM data.

This discouragement in scale and purpose leads to more complications: [21]

- Redundant or overly detailed BIM content must be abstracted or removed before use in CIM systems.
- Nevertheless, important information (e.g. building function, material properties, energy assessments) must often be retained - even when simplifying geometry.
- There is no standardized pipeline for LOD translation, so these transformations are usually performed manually or through the ad-hoc script, and introduce inconsistency and inefficiency.

Addressing this problem requires more than just data defect- it also requires semantic justification to identify what information is really contextually relevant in the urban scale. Promising strategies include rule -based generalization, hierarchical modeling and parametric abstraction, but widespread adoption is still limited due to the lack of uniform tools and guidelines.

Lack of Shared Ontologies and Vocabularies

Another obstacle to semantic interoperability between BIM and CIM is that there are few widely agreed-on shared ontologies and standardized vocabularies that can provide easy interchange between the two. Ontologies are formal means for defining domain-specific knowledge and relations. Within BIM, the use of the IFC ontology is widespread in the domain of building construction, while *CityGML*, *INSPIRE*, or *GeoSPARQL* are commonly used in the geospatial domain by CIM. Ontological mismatch introduces semantic gaps as well as inconsistencies:

- General BIM and CIM principles are usually given different names (e.g., “*IfcWall*” in IFC vs. “*WallSurface*” in *CityGML*), causing confusion when data is being exchanged.
- The hierarchical relationships such as part-of or composed-of are denoted in separate manners in each domain, so maintaining the semantics is difficult when translating complex entities.
- A widely accepted crosswalk or semantic dictionary is not available to map or match between BIM and CIM schemas.

Onto BIM, GeoBIM, and the W3C Linked Building Data Community Group have all worked towards defining common vocabularies and alignment models. All are founded on *OWL (Ontology Web Language)* and *RDF (Resource Description Framework)* to do semantic graph definitions between BIM and GIS constructs. These remain mainly theory/prototype and are not included in industry-standard tools/workflows. Moreover, the lack of available systems that

can dynamically adapt BIM and CIM ontologies continues to hinder large-scale integration. For the majority of practical cases, semantic translation is manually carried out involving domain knowledge as well as significant resources.

To address this challenge, future initiatives should aim to:

- Cross-domain ontology construction that standardizes connections between *IFC* and *CityGML*.
- Developing standardized vocabularies for significant urban terms that span building to city scales.
- Innovating automated reasoning engines to detect semantic equivalencies, resolve conflicts, and facilitate smooth domain-to-domain data exchange.

Common semantic alignment is crucial to realizing the full potential of urban digital twins, which will drive scalable, accurate, and interoperable models from building components to whole cities.

Semantical Alignment Techniques

To find a solution to the traditional dilemma of semantic incompatibility between Building Information Modelling (BIM) and City Information Modelling (CIM), more than band-aid solutions are needed; instead, a standardization of methods based on experience in the field as well as scholarly study is required in the discipline. A number of promising solutions have been proposed that seek to bridge the semantic and ontological gaps between these two fields and all of which provide a mechanism to allow more consistent large-scale integration of information. The other method commonly used is via ontology mapping and mediation software which allows partial or complete translations between the IFC schema presented by BIM to the CityGML standard presented by CIM. Some of the tools that have facilitated such translations are FME, IfcExplorer and 3DCityDB. The semantic web technologies used in higher end systems like Web Ontology language (OWL) and the Resource Description Framework (RDF) with the help of which the relationships between the domain-specific concepts can be formalized in machine readable form. These technologies are semi-automated or automated mapping, making it take less work and being more reliable. [2]. The other strong technique is the use of Application Domain Extensions (ADEs) in CityGML. CityGML is a modular structure that can be extended using ADEs to include new attributes or domain classes without affecting the integrity of the core model. It can then be of use in embedding fine-grained BIM content (e.g. internal mechanical systems or multi-levelled construction assemblies) in urban-scale CIM models -while achieving more powerful data integration with structure consistency. BIM to CIM and vice versa translation is not always efficient and feasible. To resolve this, both researchers and developers proposed the use of hybrid data model or the use of intermediate schemas. [19]. These are

fundamentally a semantic broker between BIM and CIM that hides a lot of the cumbersome building information into something that will simply conform to the needs of the city-wide platforms. Ontologies like Geo BIM have been proposed in the same regard, the application of which will enable an easy semantic layer and ease of translation, as well as interoperability.

Finally, semantic web and linked data provide a more scalable and flexible basis of integration. When URIs are used to identify the objects in the data and the vocabularies adopted are agreed upon by all, these solutions will allow decentralized but networked systems in which the information can be queried, reused, and extended across platforms and jurisdictions. This is both as technical interoperability as it is as an enabling feature in wider trends towards open data government and smart city platform strategies. Overall, these technologies support the significance of formal and machine-readable models to support the semantic gap between BIM and CIM. They establish a platform on which to build coherent, large-scale processes that can be tailored to many diverse requirements, including urban planning as well as real time urban management.

Towards a Semantic Interoperability Layer in BIM-to-CIM Frameworks

While the above methodologies provide helpful tools for dealing with semantic differences between BIM/CIM, overall, still to be gained is the benefit from more unifying, systematic solutions—a particularly significant need as scales of integration increase through heterogeneous urban contexts. To this end, the approach under consideration recommends the use of a dedicated Semantic Interoperability Layer as an intelligent, modular entity situated in the broader BIM-to-CIM Integration Framework.

This semantic level will provide the motivating force for domain-to-domain alignment, mediation, and translation of the semantics of data. It will possibly change object classes and attributes between CITYGML and IFC forms using rules and logical definitions that are pre-given. Apart from low-level form mapping, this will also include level of detail (LOD) generalization, automatically adjusting model granularity to match the application context minimization of data overload while preserving prominent information.

The third team, besides, would incorporate ontology -based reasoning to recognize discrepancies, fill out holes, as well as verify associations across domain. The layer would also provide semantic flexibility to models that evolve as well as standards that change, changing mappings as well as associations automatically to adapt to new needs or schema structure changes. The adoption of such a layer will dramatically reduce the requirement for manual intervention, ensuring enhanced consistency and efficiency in BIM-to-CIM data transfers. It will also maximize the scalability and reusability of the framework, allowing for flexibility to suit diverse cities, models of government, as well as technical infrastructures. Most importantly, this semantic layer redefines interoperability—

not as that initial conversion challenge but as an in-use capability that facilitates cities to capture the full promise of integrated digital twins. Through the bridging of the semantic gap in a durable, flexible manner, this approach lays the ground for smarter, responsive urban environments.

SCALING FROM BIM TO CIM

The transition from building information modeling (BIM) to Urban Information Modeling (CIM) represents one of the most challenging, but critical development in the development of smart and sustainable city systems. While BIM operates in the scope of individual buildings, CIM must integrate data across neighborhoods and entire cities, requiring both technical and conceptual frameworks that are able to handle tremendously greater complexity.

Analysis of pilot projects

Early pilot projects demonstrate both the lifting and the challenges of scaling digital models from micro (building) level through the *Mesoscale*- Meso (neighborhood or district) to the macro (city-wide) scale. This transition with multi-scalar is crucial to the development of Building Information Modelling (BIM), which focuses on detailed data modelling level, to Urban Information Modelling (CIM), which integrates complex systems into an entire city. Initiatives such as Virtual Singapore, Helsinki 3D City and Dubai's digital twin exemplify how information on the building can feed into city -wide platforms to enable district energy simulations, urban planning of cities and disaster modeling.

At the same time, they reveal the difficulties with this transition, especially when it comes to data interoperability, semantic mismatches between building-oriented and urban-oriented data sets, and the management challenges associated with multi-interest platforms.

Within this process, the Meso scale appears as a critical brochure that ensures continuity and ease of use across scales. At the micro-level, BIM models contain exhaustive details-down to building materials and building systems-which is too granular to be directly useful for urban planning. Conversely, CIM at macro -level requires generalized, abstract data that is adapted to policy formulation and city council. The meso scale solves this tension by serving as intermediate filter and translator: It collects micro-level information for manageable datasets, while still retaining enough granularity to catch the relationship between buildings, infrastructure and public space on the neighborhood scale. The role of the Meso scale extends beyond aggregation.

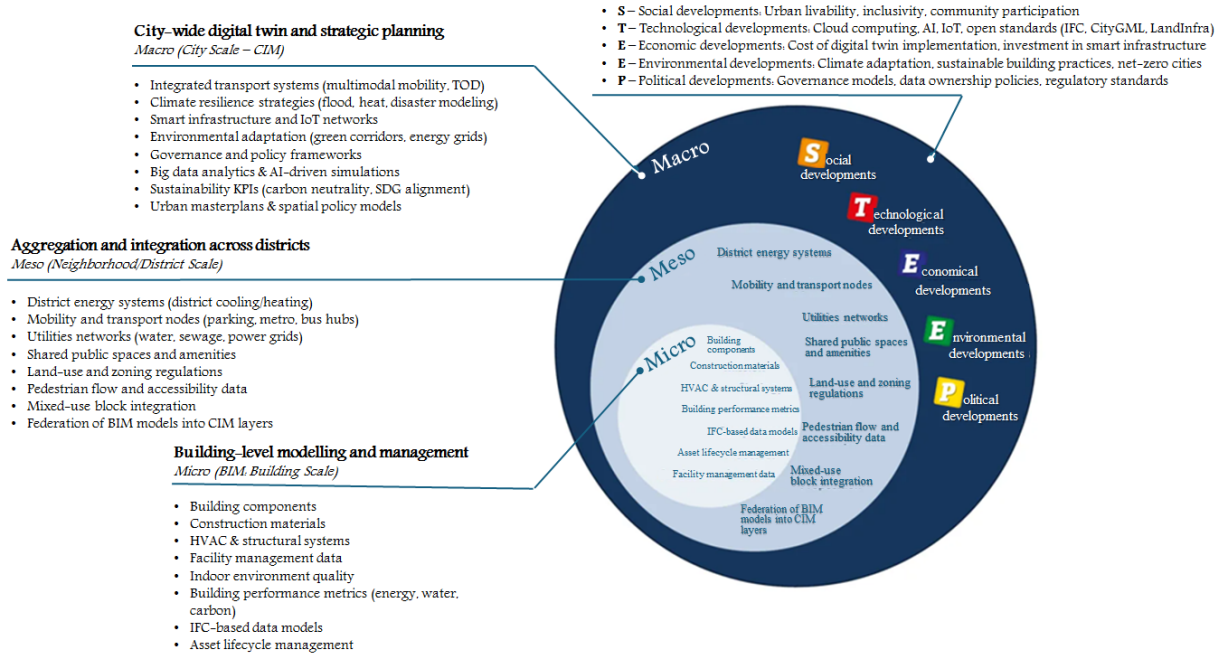


Figure 4: In micro- and macro-scales, the "Meso" (or Mesoscale) is an intermediate, mid-level scale that bridges the gap between the very small (micro) and the very large (macro). It focuses on phenomena, structures, or interactions that are not atomistic but also not large-scale continuums (by author)

It also provides contextualization of function, and acknowledges that buildings do not work in isolation, but interact with surrounding land use, tools and mobility systems. Phenomena such as pedestrian streams, district energy networks or localized transport nodes are best captured at this intermediate level. In addition, many sustainability and viability policies, such as district cooling systems, 15-minute urban principles, or waste and water management strategies, are most effectively implemented on the neighborhood scale. Thus, the Meso scale becomes a test site where interventions can be modelled and evaluated before scaling up to the macro level.

Equally important is the semantic role of the Meso scale. BIM data is primarily designed for engineers and architects, while CIM and GIS data serve planners and decision makers. The MESO level acts as a semantic bridge, and translates very technical design details into broader descriptions relevant to urban control, such as density measurements, regulatory categories or energy efficiency indicators. By doing so, it facilitates dialogue between different professional domains and ensures that intelligence at the building level is meaningfully integrated into the city's decision-making macro-scale platforms.

In brief, the meso scale is not merely a transitional step between micro and macro. It is a critical enabler that allows BIM logic to expand into CIM domains without losing either detail or relevance. By acting simultaneously as a translator, integrator, and testing platform, the meso scale makes possible a multi-scalar approach to digital urbanism in which building-level information and city-wide strategies are seamlessly connected. Without it, attempts to scale risk become either too fragmented- if detail is lost in abstraction- or too superficial—if macro-level generalization overrides local realities. [24]

Technical Activate

Scaling is made possible by several technical enablers. Cloud computing provides infrastructure to store and process massive data sets on urban scales, ensuring accessibility and scalability across stakeholders. Open standards such as IFC, CityGML, and LandInfra (*an Open Geospatial Consortium (OGC) specification for modelling land and civil engineering features, intended to bridge BIM and GIS technologies*) are important to bridge the data gap between building level and urban level, which enables semantic interoperability. [25] Automation and artificial intelligence further enhance this process by streamlining repetitive tasks such as data conversion, geometry validation and classification, enabling thousands of BIM objects to be integrated into a continuous *CIMEnv*, where they can support high-level urban applications. Together, they create technical backbones for enabling scaling, which makes it possible to transform highly wide building-level data on the neighborhood and city parameters into actionable insights. Nevertheless, technology alone does not guarantee successful scaling. [26] This process should also be supported by conceptual ambitions that provide a theoretical and organizational structure for integration. The hierarchical modelling is an approach that can structure urban systems in nested levels - construction, blocks, districts and cities - so that detailed BIM data can be selected for use in comprehensive CIM contexts. [27] Data abstraction carried forward this infection by filtering and normalizing the information, ensuring that only the relevant characteristics are moved forward without overwhelming the high-level model with unnecessary expansion on each scale. Finally, the Federation technique allows various models and datasets to be partially independent, while still the inter non-shelter holders are able to contribute to a shared city model without abandoning the ownership of their own data. [21]

In practice, the interconnection between technical ambassadors and conceptual structures is the one that is possible from BIM to CIM. Cloud computing, AI, and open standard raw power and differences, while hierarchical modelling, abstraction and federation ensure that this power is applied in a structured, meaningful way. Without this dual foundation, the efforts to transfer the city-level information risk from the building-level became either technically

fragmented or ideologically incompatible, which reduces the value of digital urbanism as a tool for the development of a smart city. [25]

Conceptual Enables

Equally important are conceptual enables that provide a theoretical basis for integration. Hierarchical modeling allows the breakdown of complex urban systems in layers (e.g. construction, block, district, city), and preserves both details and scalability. Data abstraction techniques reduce information overload by representing important attributes at each level of analysis, and ensuring that models remain usable without sacrificing precision where needed. [28] Finally, federation techniques enable linking multiple data sets or models without requiring full association, so that stakeholders can maintain control of their domains while still contributing to an integrated CIM framework. Overall, these enables the enables that scaling from BIM to CIM is not only a matter of increasing the data volume, but requires a basic thought of how information is structured, divided and used across spatial and institutional boundaries. This transition provides the basis for smart urban applications that rely on multi-scale, interoperable and adaptable models-Alt from energy optimization to climate protection and urban mobility control. [23]

THE BIM-TO-CIM INTEGRATION FRAMEWORK (BCIF)

Starting Point: BIM (Building Information Modelling)

The proposed framework, *BCIF*, views BIM as a digital twin of a single building. It contains everything an architect, engineer, or planner will need: walls, windows, floors, materials, pipes, air conditioning systems, energy use and even cost or maintenance plans.

- Example: A digital model of a hospital that not only shows the 3D geometry, but also what each wall is made of, how much energy the lights use, and when the lifts need service.

BIM is very detailed, but all these details are too much to handle when trying to plan for an entire city. That is why the *BCIF* needs a way to scale up. The following figure presents the BCIF framework, which explains the multi-scale layers required to integrate building information modeling (BIM) with Urban Information Modeling (CIM). The Process Begins with Data Breakdown and Normalization, Where Bim Models Are Aligned to A Regular Coordinate System, Geometries Are Validated, and Metadata is Standardized. The next step is semantic mapping, which translates BIM-specific terminology into CIM language to fit the broader scope of urban planning. Through the Meso bridge, detailed building information becomes abstract to aggregated indicators such as energy use, carbon footprint and total floor space per block, while geometries are

simplified to city scale models (LOD2/LOD3). The framework also emphasizes Federation, and ensures interoperability by connecting each building model to unique IDs and APIs, treating the system as a library of paired assets. Finally, within the CIM setting, this information is combined with GIS, transport network and environmental data sets to make simulations city-wide, strategic decision-making and resilient urban planning possible. This multi-tiered strategy creates continuity between building scale and city scale management, and offers a holistic way to digital urbanism.

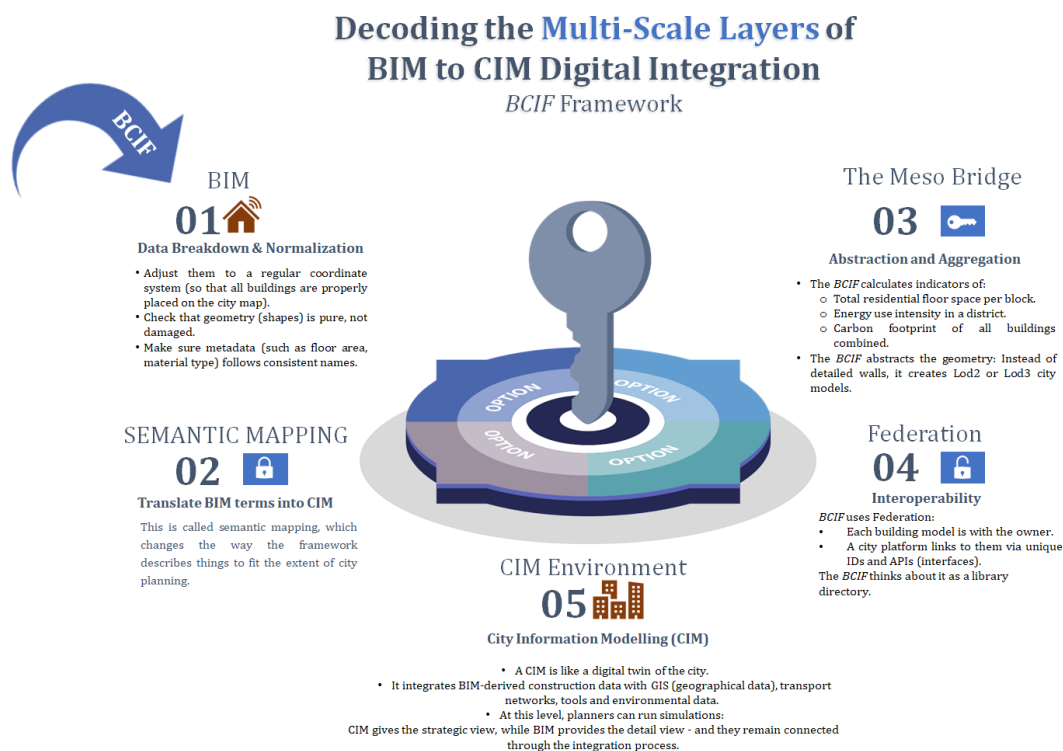


Figure 5: The BCIF Framework – Multi-Scale Integration Process from BIM to CIM through Normalization, Semantic Mapping, the Meso Bridge, and Federation (by author)

The Need for Integration (Why BIM → CIM?)

After BIM models are collected and cleaned (step 1), the next major obstacle is that BIM and CIM do not speak the same language. BIM uses classifications suitable for construction and construction management, while CIM (and GIS) needs information that makes sense for urban planners, decision makers and city managers. The process of translating this "language" is called semantic mapping.

- **Why it does matter**

- BIM describes objects in extreme technical details: e.g. *IfcWall* standard case, *ifc pipe segment* or *IFCDOOR*.
- CIM and GIS describe objects more generic: for example, building facade, benefit network segment or access point.
- Without translation, the BIM data is either too nice to be useful, or completely incomprehensible to urban systems.

Step One- Data Breakdown and Normalization [26]

The *BCIF* Framework starts by collecting BIM models from different buildings (e.g. offices, schools, apartments). These models come in different file types, and often use a standard called IFC.

- The first task is to normalize them:
 - Adjust them to a regular coordinate system (so that all buildings are properly placed on the city map).
 - Check that geometry (shapes) is pure, not damaged.
 - Make sure metadata (such as floor area, material type) follows consistent names.

This step makes sure all buildings “speak the same language” before we integrate them.

Step Two – Semantic Mapping (Translation of BIM Data) [4]

After BIM models are collected and cleaned (step 1), the next major obstacle is that BIM and CIM do not speak the same language. BIM uses classifications suitable for construction and facility management, while CIM (and GIS) needs information that makes sense for urban planners, decision makers and city managers. The process of translating this "language" is called semantic mapping.

- **Why it does matter [4]**

- BIM describes objects in extreme technical details: e.g. *IfcWall standard case*, *ifc Pipe Segment* or *IFCDoor*.
- CIM and GIS describe objects more generically: for example, *Building facade*, *Utility network segment* or *Access point*.
- Without translation, the BIM data is either too fine to be useful or completely incomprehensible to urban systems.

- **The Process of Semantic Mapping**

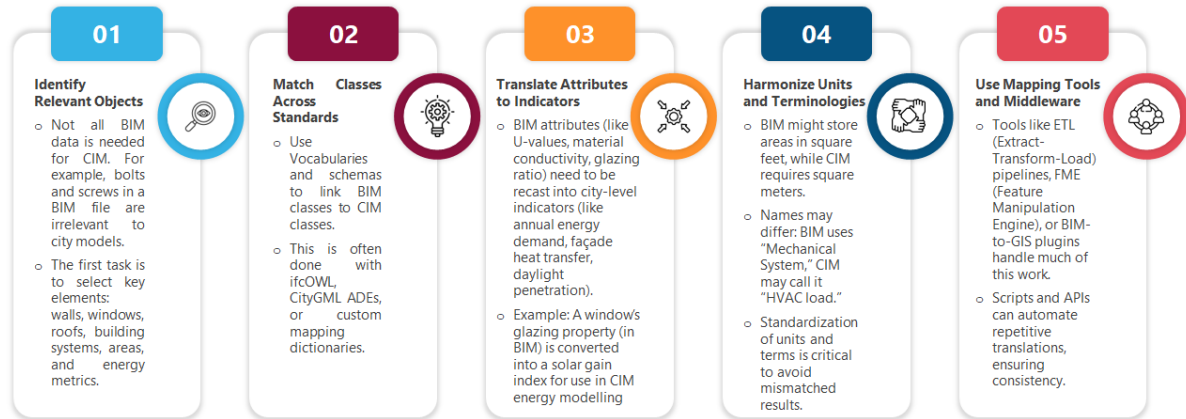


Figure 6: Stepwise Workflow of BIM-to-CIM Integration, Illustrating Data Flow Through Normalization, Semantic Mapping, Aggregation, and Federation Toward a City Information Modelling Environment (by author)

- Practical Example

Suppose we have a BIM model of a shopping center:

- In the BIM lists the models: *IfcWall Standard Case* with thickness, material (concrete), thermal resistance, etc.
- Through semantic mapping, this is translated into CIM as: *Exterior wall surface* with attribute *thermal performance rating* = medium.
- The shopping center's *IfcSpace* entries (shops, corridors, food courts) are translated into building part elements in CIM, so that planners can evaluate the relationship between the floor-area ratios, occupancy density and distribution of land use at the district scale.

- The outcome of step 2 [3]

By the end of semantic mapping:

- BIM objects are reclassified in broader rating categories.
- Detailed technical data becomes abstract in planning indicators.
- A shared semantic team is created, making BIM data interoperable with CIM and GIS systems.

Step Three – Abstraction and Aggregation (The Meso Bridge) [7]

This is where Meso Scale (neighbourhood/district) plays its key role.

- Instead of displaying each door and piping from BIM, the framework – for example- calculates indicators of:
 - Total residential floor space per block.
 - Energy use intensity in a district.
 - Carbon footprint of all buildings combined.
- The *BCIF* also abstract the geometry: Instead of detailed walls, it creates Lod2 or Lod3 city models (simplified 3D blocks with ceilings and windows).

So, the Meso scale summarizes data at the building level to be usable information for neighbourhoods, while at the same time being traced back to the original BIM when needed.

Step Four – Federation and Interoperability [7]

Here, integration does not mean dumping all data in a giant file (which will be unmanageable). Instead, *BCIF* uses Federation:

- Each building model is with the owner.
- A city platform links to them via unique IDs and APIs (interfaces).
- The *BCIF* thinks about it as a library directory. In other words, *BCIF* doesn't move all the books into a great book; it only makes them searchable and referable.

In this way, cities can connect to several datasets as transport, energy, regulation, tools, without breaking ownership or safety.

Step Five – City Information Modelling (CIM) [4]

When the data is mapped and collected, it enters the CIM environment:

- A CIM is like a digital twin of the city.
- It integrates BIM-derived construction data with GIS (geographical data), transport networks, tools and environmental data.
- At this level, planners can run simulations:
 - How to add a new bus line reduces car addiction.
 - How much CO₂ emissions can be saved by retrofitting 30% of the buildings.
 - What areas will flood if the sea level rises by 0.5 meters.

CIM gives the strategic view, while BIM provides the detail view - and they remain connected through the integration process.

The Outputs of Integration

At the end of this process, you have:

- A city model enriched with real building intelligence.
- KPIs (Key Performance Indicators) at the district level (energy, carbon, accessibility).
- A platform where a planner can zoom out for a city view but also drill down into an individual building if needed.

At the end of this process, we will have:

- A city model enriched with real building intelligence.
- C-KPIs (important performance indicators) at the district level (energy, carbon, availability).
- A platform where a planner can zoom out after a view of the city, but also drill down in an individual building if necessary.

In short, BIM can be regarded as the "microscope" (detailed views of a building), while CIM is the "telescope" (strategic views of the city). Meso Scale is the "translator and bridge" between the two.

Real-Life Implementation of the BCIF Framework

In order to illustrate the practical relevance of the suggested BIM-to-CIM Integration Framework (BCIF), a hypothetical implementation scenario may be taken in a university campus district. Here, the BIM models of each campus building, *i.e. libraries, laboratories, administrative buildings, and residential buildings*, are first gathered and standardized in the input layer of the framework. Such BIM models usually comprise rich data regarding building geometry, building materials, mechanical systems, space organization and functional characteristics.

BCIF– BIM to CIM data flow



Figure 7: Workflow illustrating the application of the BIM-to-CIM Integration Framework (BCIF) within a university campus district. The diagram shows the transition from building-level BIM models to district-level CIM analytics through semantic mapping and meso-scale aggregation.

In the semantic mapping step, the BIM objects of IfcWall, IfcSpace and IfcRoof are converted to the corresponding concepts of CIM and GIS worlds, i.e. the building surfaces, building units and functional zones of the city models in CityGML. Such a semantic transformation is necessary to make sure that the finer details of building level information can be read in the right way in larger urban modelling platforms and applied to urban level analysis and decision-making. The meso-scale aggregation process, which follows semantic translation, transforms the detailed information on BIM into district-level indicators, which can be analyzed on a city level (Figure 8).

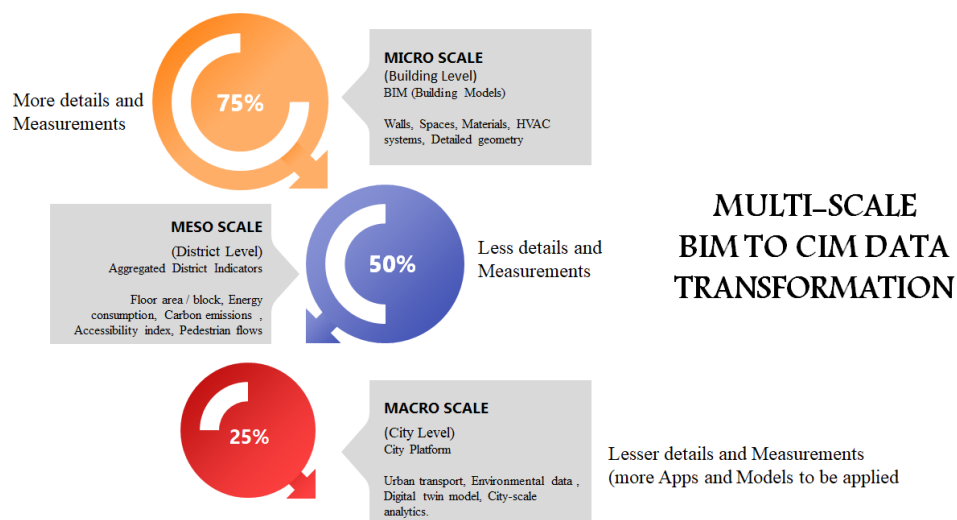


Figure 8: Multi-scale data transformation within the BCIF framework, illustrating how detailed BIM information (micro scale) is aggregated at the district level (meso-scale) and integrated into city-level CIM systems (macro scale).

Instead of reflecting each individual architectural element, building-level data is combined into useful urban metrics. As an example, multiple BIM models in the campus setting can be combined to produce indicators that include the total floor area per block, the intensity of energy use in a district, carbon emissions associated with building operations, and accessibility indices based on spatial connectivity and patterns of pedestrian movements. [29] These aggregated indicators are merged with other urban datasets at the CIM level, such as transport networks, green infrastructure systems, environmental monitoring data and the configurations of public spaces. In this combined urban framework, planners and decision makers are able to conduct simulations to test different urban development scenarios. Some examples are determining the possible decrease in carbon emissions by constructing retrofitting plans, determining the increase in

energy efficiency at the district level, or discussing the effect of new transportation paths on accessibility in the campus environment.

In spite of such opportunities, there are also a number of practical challenges in the implementation of the BCIF framework. These are the calculation needs of processing large volumes of detailed BIM data, institutional barriers in terms of exchanging data between various stakeholders, and the absence of completely standardized ontology mapping tools, which can automatically transform BIM schemas into CIM-compliant formats. [30] To address these issues, additional evolution of automated semantic translation tools, more effective interoperability criteria between BIM and geospatial systems, and the creation of effective governance frameworks to support the secure and efficient integration of data in the urban digital twins will be required.

CONCLUSION AND FUTURE WORK

The shift in the paradigm of Building Information Modelling (BIM) to the City Information Modelling (CIM) is the beginning of the new concept in the conception, management and experience of built environments. The paper has discussed how the incorporation of BIM into CIM systems can be used to develop multi-scale, semantically interoperable digital twins that are no longer limited to a single building but rather extend to the entire cities. By comparing Virtual Singapore, Helsinki 3D City, and the Dubai Digital Twin, the research found a group of similar issues, most notably the lack of semantic compatibility, data heterogeneity, and scalability, that still hinder interoperability among digital urban platforms. The BIM-to-CIM Integration Framework (BCIF) is proposed as the direct answer to these problems. The BCIF offers a coined route of converting detailed BIM datasets into city-scale CIM environments by introducing controlled steps of normalization, semantic mapping, abstraction using the meso scale, and federated data integration. This layer approach is an intermediary between the micro (building) and macro (city) level by serving as a translator and integrator of the information, that is, the accuracy of the architectural information is maintained, and at the same time, the strategic requirements of the urban management. The resultant framework has provided a platform to strong, evidence-based, and interoperable digital urbanism, the kind that can support real-time analysis, sustainability scrutiny and adaptive planning.

One of the most important lessons that this study taught is that semantic interoperability should not be seen as a single conversion but as an ongoing dynamic process. The fact that a specific semantic interoperability layer is embedded in the BCIF makes sure that the actions of ontologies, standards, and technologies evolving do not get out of sync due to the unnecessary manual maintenance. Correspondingly, multi-scale modeling and federated integration maintain data sovereignty, as well as system scalability, allowing institutional, disciplinary and jurisdictional participation.

The future study of the BCIF must be interested in operationalizing and empirically validating it in practical settings. This includes:

- Creation of automated ontology alignment tools which are used to map IFC-CityGML in a variety of settings.
- Running the framework on live digital twin infrastructures on real-time IoT data streams.
- Increasing the flexibility of the framework with AI-based semantic reasoning that is used to expand predictive analytics and decision support.

Finally, BIM and CIM integration within the proposed framework is not merely a synthesis on a technical basis, but an indication of a new direction to the truly positive digital urbanism, whereby data will be flowing across scales, disciplines, and time. Aligning the micro-scale level of accuracy with the macro-level of governance, the framework also leads to the development of smart, sustainable, and people-oriented cities that are digitally consistent and contextually grounded.

REFERENCES

- Al-Kazee, M. F. M. M. R. R., & S. I. M. (2025). An investigation of barriers to adopting building information modeling (BIM) in the AEC industry of developing countries: A critical review. *Civil and Environmental Engineering*.
- Al-Kazee, M. F., & Ramhamdani, R. (2022). The adoption of BIM technology in the architectural consultancy firms in the GCC region. *Civil Engineering and Architecture*, 10(1), 280–288. <https://doi.org/10.13189/cea.2022.100124>
- Batty, M. (2018). Digital twins. *Environment and Planning B: Urban Analytics and City Science*, 45(5), 817–820.
- Cheng, J. C. P. D. Y., & A. C. (2015). Mapping BIM schema and 3D GIS schema semi-automatically utilizing linguistic and text-mining techniques. *Journal of Information Technology in Construction (ITcon)*, 5(2), 73–91.
- City of Helsinki. (2021). Helsinki 3D+ and Digital Twin Programme. City of Helsinki Urban Environment Division. Retrieved September 13, 2025, from <https://www.hel.fi/helsinki/en/administration/information/digital-twin/>
- Daneshfar, M., et al. (2022). An ontology to represent geospatial data to support integration of IFC and CityGML. *Spatial Information Research*.
- Dubai Municipality. (2020). Dubai Digital Twin initiative. Government of Dubai. Retrieved September 13, 2025, from <https://www.dm.gov.ae/dubai-digital-twin/>
- El-Mekawy, M. Ö. A., & H. I. (2012). An evaluation of IFC-CityGML unidirectional conversion. *International Journal of Advanced Computer Science and Applications (IJACSA)*, 3(5), 70–87.
- Flores, G. S. E. C., & D. E. (2018). Investigating interoperability capabilities between IFC and CityGML LOD 4 – Retaining semantic information. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-4/W, 10–33.

- Haraguchi, M. F. T., & B. F. (2024). Assessing governance implications of city digital twin technology: A maturity model approach. *Technological Forecasting and Social Change*, 204.
- Hämäläinen, M. R. J. R. T. A. M., & H. P. (2021). Urban development with dynamic digital twins in Helsinki city. *Environment and Planning B: Urban Analytics and City Science*, 48(7), 1749–1765.
- Huzzat, A. A. A. K. A. V. S., & S. A. (2025). A comprehensive review of digital twin technologies in smart cities. *Digital Twin Engineering*, 2(1), 1–23.
- Kolbe, T. H., & D. A. (2021). Semantic 3D city modeling and building information modeling (BIM). In *Urban Informatics*.
- Mazzetto, S. P. F. a. B. M. (2024). A review of urban digital twins integration, challenges and future directions in smart city development. *Sustainability*, 16(9), 18–37.
- National Research Foundation Singapore. (2018). Virtual Singapore: Building a 3D empowered smart nation. *Geospatial World*. Retrieved September 13, 2025, from <https://geospatialworld.net/prime/case-study/national-mapping/virtual-singapore-building-a-3d-empowered-smart-nation/>
- Noardo, F. B. F. E. C. H. L., et al. (2020). Reference study of CityGML software support: The GeoBIM Benchmark 2019 — Part II. *International Journal of Geo-Information / TGIS*.
- Noardo, F. N., et al. (2019). GeoBIBenchmark 2019: Design and initial results.
- Omran, H. M. A. a. O. D. (2025). The uptake of urban digital twins in the built environment: A pathway to resilient and sustainable cities. *Discover Sustainability*, 6(1), 1–15.
- Omran, H. M. A. a. O. D. (2025). The uptake of urban digital twins in the built environment: A pathway to resilient and sustainable cities. *Discover Sustainability*, 6(1), 1–15.
- Reference study of CityGML software support: The GeoBIM Benchmark. (2019).
- Şenol, H. (2024). A new approach for IFC to CityJSON conversion ensuring geometric & semantic integrity. *Springer Journal*.
- Shareef, A. T. B. a. V. N. (2023). Semantic interoperability of digital twins in smart cities. *International Journal of Digital Innovation in the Built Environment*, 12(3), 45–63.
- Shi, J., et al. (2023). An ontology-based methodology to establish a general CIM ontology to integrate heterogeneous BIM, GIS, and IoT data. *Spatial Information Research*, 23(4), 123–141.
- Souza, L. B. F. a. C. C. (2022). City information modelling as a support decision tool for urban design. *Building and Environment*, 207, 108–156.
- Tan, Y. Z. Q., & L. Y. (2023). CityGML in the integration of BIM and the GIS: Challenges and opportunities. *Buildings*, 13(7), 1785.
- Vittori, F. T. C. a. P. A. (2023). BIM-to-BRICK: Graph modelling for IoT/BMS and semantic data interoperability in building digital twins. *Automation in Construction*, 147, 104–115.
- Xue, F. W. L. L. W. W. G. C. K. a. Z. L. 2. (2021). Semantic enrichment of building and city information models: A ten-year review. *Automation in Construction*, 124, 103–577.
- Xu, X. D. L. L. H. a. M. L. (2014). From building information modeling to city information modeling. *Journal of Information Technology in Construction (ITcon)*, 19, 292–307.

Mohammed Faisal Ghazi AL Kazee, Islam Sallam

BUILDING TO CITY: INTEGRATING BIM INTO CIM FOR A COMPREHENSIVE DIGITAL URBANISM

Yu, W. M. Z. W. Y. a. X. X. (2025). The development and construction of city information modelling: A data-centric perspective. *Applied Sciences*, 15(9), 46–96.

Zhu, X. L. W. C. H. W. Y. a. Z. H. (2025). Data-driven urban digital twins for critical infrastructure resilience. *Urban Planning*, 10(2), 131–146.

Received: 20th December 2025. Accepted: 13th January 2026