

DEVELOPING A FRAMEWORK TO INTEGRATE ACCESSIBILITY DESIGN GUIDELINES INTO OPENBIM WORKFLOW FOR AN AGE-IN-PLACE HOME DESIGN

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ABSTRACT: Creating inclusive environments like Age-in-Place Homes (AIPHs) needs to incorporate building codes, especially accessibility and Universal Design (UD) guidelines. However, traditional Building Information Modeling (BIM) workflows often have challenges in implementing practical design as they lack standardized methods to integrate the detailed requirements of building code. This study presents a framework that uses OpenBIM, particularly the Industry Foundation Classes (IFC), to put into practice the design of buildings based on accessibility standards and guidelines. The start will be with a comprehensive analysis of the international and local accessibility standards, including ISO 21542. All those requirements are extracted and translated into quantifiable design constraints, which form the foundation for developing custom Property Sets (Psets), systematically defined with precise data types, units, and allowable values. The use of IFC is to include comprehensive code requirements into the BIM process, the presented approach shows how OpenBIM may effectively address the gap between the building regulations and the practical implementation of designs. To attain a proper integration of these customized Psets into BIM models, a Model View Definition (MVD) is developed to outline the proper structure and IFC-based interchange of accessibility information. With this approach, designers can validate and check that their OpenBIM processes adhere to building codes. By leveraging IFC, the international standard for BIM data exchange, the framework ensures that accessibility requirements are consistently applied, regardless of the BIM authoring tools that have been used.

1. INTRODUCTION

Accessibility and Universal Design (UD) standards growth and development in Building Information Modeling (BIM) have been increasingly acknowledged as fundamental for inclusive design (Rostamiasl & Jrade, 2022). The demographic shift towards an aging population brings a critical need for global housing solutions for older adults' special conditions requirements. Age-in-place houses (AIPH), as a practice and example of accessibility and UD standards and guidelines, which allow the elderly to live independently in their homes for as long as they want and can, are becoming increasingly important. Yet, designing such homes involves complex considerations, including accessibility and sustainability (Aging in Place, 2023; Gomes, 2021; Statistics Canada, 2022).

To address the growing need for information sharing in digital architecture, shifting the planning process from a restricted digital environment, known as ClosedBIM, to an OpenBIM workflow is crucial. In a ClosedBIM setting, the planning participants collaborate on a single building model designed in a specific (proprietary) data format, which is feasible only when facilitated by software from a single vendor's application suite (Horn et al., 2020).

The concept of Model View Definition (MVD), as an established BuildingSMART concept within OpenBIM workflows, is an important component in facilitating a standardized exchange of data. It represents a

particular implementation of IFC entities to support its specific application for straightforward exchange scenarios, covering both geometry and semantics, defining relationships, and property sets that are in scope, along with rules for their use (e.g., requiring certain attributes or referencing certain Psets) (buildingSMART International, 2025; Tang et al., 2020). Employing OpenBIM is promising since it supports the adaptability of data and the collaborative use of neutral data formats like IFC. It is paving the way for data to seamlessly be exchanged between different computer tools, tailoring the import and export of data in incompatible and customizable formats to each specific BIM application to become possible and accessible (*BuildingSMART International*, 2024).

With the help of custom Psets and MVD, this research proposed a framework that defines and creates a structured and standardized method for representing accessibility and UD codes within the OpenBIM concept. This approach will provide a foundational structure to facilitate the transfer of data and its compatibility with the different tools and platforms.

2. BACKGROUND

In building design, accessibility depends on recognized standards that specify criteria for the design elements such as door widths, ramps, grab bars, and maneuver spaces. The Americans with Disabilities Act (ADA Standards for Accessible Design, 2010) requires minimum door clearances, ramp slopes, and grab bar placements to accommodate wheelchair users. Similarly, the Canadian Standards Association (CSA) B651-18 (CSA Group, 2012) aligns with the National Building Code of Canada (NBCC) (2020) to regulate barrier-free paths, handrail dimensions, and spatial allowances. At the international level, NBCC, (2021) provided a structured framework for accessibility by specifying the specifications for designing accessible buildings, surface requirements, signage, and usability criteria, which makes it appropriate and applicable for BIM-based accessibility validation.

Recently, many studies highlighted the importance of implementing accessibility regulations, which can bring opportunities and challenges to the BIM workflow. For instance, Rostamiasl & Jrade, (2022) developed a plugin to implement accessibility guidelines within BIM workflow and to increase the accessibility compliance with the focus on adopting UD principles at the early stage of design. Similarly, Izbash & Babayev, (2024) discussed the digitization of building codes and the shift toward machine-readable accessibility standards, highlighting the importance of structured databases for regulatory compliance, the challenges of integrating regulatory requirements into BIM-based workflows, and the need for structured and standardized approaches. Kładź & Borkowski, (2024) highlighted the importance of incorporating accessibility assessments into BIM workflows through a laser scanning and digital modeling and how the manual compliance checking is inefficient, with the emphasize on the need for automated processes.

MVD serves as an implementation extension of the Information Delivery Manual (IDM), it standardizes information flow for specific use cases and brings the expected content within each data exchange. It provides a structured mapping of data exchange requirements onto IFC schema, ensuring interoperability in BIM workflows and the various tools used in the design, construction, and operation phases (Horn et al., 2020). If compared to the full IFC datasets, MVD provides only the necessary information that is structured, extracted, and shared (buildingSMART International, 2025; Jiang et al., 2019; Ramaji et al., 2020). Moreover, MVD ensures that only the necessary information is structured, extracted, and shared, thereby optimizing efficiency in BIM workflows. An example of implementing MVD-targeted energy modeling workflows was introduced by the US General Services Administration (GSA) through GSA-03 MVD. It was designed to facilitate the exchange of data from BIM tools to energy simulation models, primarily including Geometric space data, Spatial boundary geometry (for openings, doors, windows, slabs, and walls), Layering and material details of walls and slabs, Thermal properties of walls and windows. Over the time, GSA-03 was merged into a broader MVD framework (GSA-05), which was incorporated into the National BIM Standard–United States (NBIMS-US) (NIBS, 2016; Ramaji et al., 2020). Ramaji et al., (2020) utilized the GSA-05 MVD as a foundation for exporting IFC-based BIM models to be transformed into Building Energy Modeling (BEM) formats. However, since not all the necessary attributes needed for an accurate energy simulation model were covered by GSA-05, an extension of the MVD was required to accommodate

additional properties, which includes IES file location for lighting fixture definitions and energy-related attributes for the window and door elements. The workflow relied on a custom IFC exporter for Autodesk Revit, qualifying for the automation of additional property exports to maintain consistency with the MVD extension.

Whereas Horn et al., (2020) developed an IFC-based approach to integrate Life Cycle Assessment (LCA) into BIM workflows with the focus on data exchange standardization through MVDs, and they introduced a new data structure as the “Lifecycle Element” to facilitate the integration of LCA with BIM. While Jiang et al., (2019) structured MVD subsets tailored for multi-disciplinary workflows by enabling software-independent data exchange, and introducing a rule-based approach for automated compliance checks, where MVD-based IFC models were validated against building regulations. On the other hand, Tang et al., (2020) pointed to the Building Automation Systems (BAS), where MVDs can help in a structured exchange of information between BIM tools and control systems, and yet can introduce user-defined Psets and property enumerations by ensuring that BAS-related parameters are represented within the IFC models. Weise et al., (2016) illustrated how specialized domain data, including custom labeling and classification needs, cannot be fully addressed by standard IFC property sets. This highlights the need to develop additional or custom property sets that go beyond the default IFC property set options, especially for complex or project-specific requirements that exceed the limitations of the standard schema. Jaud & Clemen, (2024) show that georeferencing often requires extra data (CRS info, rotation/translation parameters) beyond what standard IFC property sets provide. They must use specialized property sets (e.g., EPset_ProjectedCRS) or MVD expansions to store and validate these details, which underlines a broader limitation in the default IFC Psets for advanced use cases like robust georeferencing.

Analyzing the literature and identifying the gaps led to a conclusion that there is a need for a standard approach since many accessibility and universal design elements (e.g., wheelchair turning radius, door clearances, grab bar locations) do not have predefined IFC entities or Psets. The proposed framework in this study translates accessibility codes into structured, quantifiable IFC-based Psets and directly addresses the lack of standardization identified in the previous studies. Unlike the existing research that focuses on digital representation, this research goes one step further by defining the data structures that can be used across the different BIM tools.

3. METHODOLOGY

Implementing (ISO 21542, 2021) requirements, as an example, are translated into measurable criteria (e.g., minimum clear width, maximum counter height, slip-resistant floors, reachable range) in an IFC-based OpenBIM workflow by examining the IFC4 schema to pinpoint the key objects relevant to AIP design, such as `IfcSpace` (for rooms, kitchens, hallways), `IfcDoor`, `IfcSanitaryTerminal` (for sinks, toilets), and potentially `IfcFurniture` (for countertops or cabinets if needed). Including both geometry and property definitions; Custom Psets were created and defined as compatible with ISO 21542, to be extracted and organized based on the definition requirement sets and structure required by BuildingSMART International. Level of Detail (LOD) focuses on property constraints and geometry/representation constraints. The next step is to define an MVD, ensuring that accessibility requirements based on different standards and guidelines in an IFC model have specific geometry and classification. Figure 1 presents an overview of the methodology.

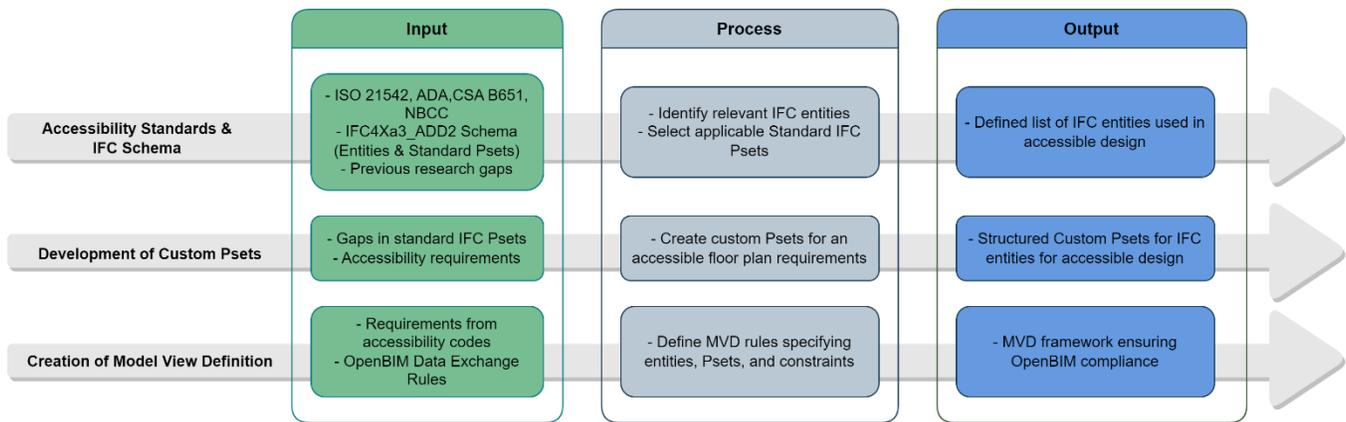


Figure 1: Methodology's overview

4. STRUCTURING CUSTOM PROPERTY SETS (PSETS) FOR ACCESSIBILITY & UNIVERSAL DESIGN

Considering that IFC was designed to be extensible via custom property sets (*BuildingSMART International, 2024; Ramaji et al., 2017*), where industry or project-specific needs, such as accessibility or sustainability, could get incorporated when standard IFC Psets do not cover them. Psets allow IFC objects (e.g., `IfcDoor`, `IfcSpace`) to store accessibility-specific data. Standard IFC property sets (e.g., `Pset_DoorCommon`) do not cover specialized universal design features (e.g., slip-resistant floor property, or adjacency constraints). Applicable codes are mapped to their related IFC entities after being identified. As detailed in Table 1, a sample structure of the custom Psets, based on ISO 21542, is provided. They are structured like `Pset_AccessibleKitchen`, or `Pset_AccessibleCorridor`. Each property is assigned a Name (e.g., `MinTurningDiameter`), a Data Type (e.g., `IfcPositiveLengthMeasure`, `IfcBoolean`), and a Constraint (“≥ 1500 mm recommended”).

Table 1: A sample part of the developed custom Psets

Property Set Name	IFC entity	Property Name	Data Type	Requirement (constraint)
Pset_AccessibleDoor	IfcDoor	Door Width	IfcPositiveLengthMeasure	≥ 850 mm
		Clearance Depth	IfcPositiveLengthMeasure	≥ 600 mm (recommended ≥ 700 mm)
Pset_AccessibleSpace	IfcSpace	MinClearWidth	IfcPositiveLengthMeasure	≥ 1200 mm (Min.), 1500 mm (Recommended)
Pset_AccessibleCorridor	IfcSpace	MinTurningDiameter for 90° Turn	IfcPositiveLengthMeasure	≥ 1200 mm (Min.), ≥ 1500 mm (Recommended)
		MinClearHeight	IfcPositiveLengthMeasure	≥ 2400 mm
		ObstacleFreeZone	IfcBoolean	True (No handrails, fire extinguishers, coat hooks)
		TurningSurfaceLevel	IfcBoolean	True (Must be level)
		MinTurningLength for 180° Turn	IfcPositiveLengthMeasure	≥ 2000 mm (Min.)

		AdjacencyToRoom	IfcBoolean	True if adjacent to areas (kitchen, living, bathroom)
Pset_AccessibleKitchen	IfcSpace, IfcFurniture, IfcAppliance	MinTurningDiameter	IfcPositiveLengthMeasure	≥ 1500 mm
		CooktopClearance	IfcPositiveLengthMeasure	≥ 750 mm (Min knee clearance below cooktop)
		OutwardOpeningDoor	IfcBoolean	True (Required for small kitchens)
		SlipResistantFlooring	IfcBoolean	True (Required for safety)
		WorktopAdjacentToAppliances	IfcBoolean	True (Worktop must be adjacent to fridge, sink, and cooktop)
	IfcDistributionElement, IfcSanitaryTerminal	OutletWithinReach	IfcBoolean	True (Electrical outlet must be within reach of appliances)
		EasyOneHandOperation	IfcBoolean	True (Taps should be operable with one hand)
		KneeRecessProvided	IfcBoolean	Optional (Based on user needs)
Pset_AccessibleControlsAndDevices	IfcBuildingElement, IfcDistributionElement,	HeightAboveFloor	IfcPositiveLengthMeasure	800 mm - 1100 mm (for general control devices & fire alarm activators)
		SocketHeightAboveFloor	IfcPositiveLengthMeasure	400 mm - 1000 mm (for wall sockets, telephone & TV points)
		DistanceFromInternalCorner	IfcPositiveLengthMeasure	≥ 600 mm (clearance from corners)
		ControlAngle	IfcPlaneAngleMeasure	45° (for text or figures on control devices)
Pset_WheelchairManeuveringSpace	IfcSpace	WheelchairFootprintWidth	IfcPositiveLengthMeasure	800 mm
		MinTurningDiameter	IfcPositiveLengthMeasure	≥ 1500 mm (for significant direction changes)
		ObstacleFreeZone	IfcBoolean	True (Turning spaces must be free of obstructions)
Pset_WheelchairSpaceAllowance	IfcSpace	StationaryLength	IfcPositiveLengthMeasure	1500 mm (Wheelchair length when stationary)
		MinSideClearance	IfcPositiveLengthMeasure	50 mm (Min clearance for manual wheelchair)
		PreferredSideClearance	IfcPositiveLengthMeasure	100 mm (Recommended clearance for manual wheelchair)
		MinTurningArea	IfcPositiveLengthMeasure	Dependent on wheelchair type (based on ISO 21542, 1.68m ² , 2.45m ² , 4.62m ² , 3.3m ²)
		ManeuverabilityType	IfcLabel	Manual, Electric, Bariatric (Defines maneuverability characteristics)
		BackingOperationsRequired	IfcBoolean	True/False (Whether the design allows multiple backing operations for turning)
Pset_AccessibleLivingRoom	IfcSpace	MinTurningDiameter	IfcPositiveLengthMeasure	≥ 1500 mm (Required for wheelchair maneuverability)

		MinPassageWidthToBalconyDoor	IfcPositiveLengthMeasure	≥ 900 mm (Ensures access to balcony/outside space)
		MinPassageWidthToAdjoiningRooms	IfcPositiveLengthMeasure	≥ 900 mm (Ensures passage to adjoining spaces)
		FurnishingClearance	IfcBoolean	True (Ensures adequate space for furniture placement)
Pset_AccessibleBedroom	IfcSpace	MinPassageWidthFixedElements	IfcPositiveLengthMeasure	≥ 900 mm (Passage between fixed furniture, including access to openable windows)
		MinBedAccessWidth	IfcPositiveLengthMeasure	≥ 1200 mm (Min), 1500 mm (Recommended) (Space beside bed for wheelchair access)
		MinWardrobeFrontClearance	IfcPositiveLengthMeasure	≥ 1500 mm (Front-opening wardrobes)
		MinTurningDiameter	IfcPositiveLengthMeasure	≥ 1500 mm (Wheelchair turning space)
		MinTurningDiameter	IfcPositiveLengthMeasure	≥ 1500 mm (Turning circle for wheelchair)
Pset_AccessibleBathroom	IfcSpace, IfcSanitaryTerminal, IfcWall, IfcDoor,	DoorSwingDirection	IfcLabel	Outward (Hinged door must swing outward)
		SlipResistantFlooring	IfcBoolean	True (Required)
		GrabBarSupportWallStrength	IfcBoolean	True (Walls must support grab bar installations)
		WCTransferPosition	IfcLabel	Side, Front, Angled (Positions for WC transfer)
		ShowerThermostatHeight	IfcPositiveLengthMeasure	Reachable height (800 mm - 1100 mm)

5. PROPOSED MODEL VIEW DEFINITION (MVD) FOR ACCESSIBLE AIPH

Following the BuildingSMART International MVD structure, as illustrated in Figure 3, a sample of the MVD is created. The highest-level container in an MVD is Model View, which provides a name for users that this MVD specifically addresses universal design constraints for age-in-place homes. Next, ConceptRoot, specifies the corresponding IFC entities with the associated rules to which they are being applied, for instance, a ConceptRoot for IfcSpace can be “AccessibleBathroomRequirements”. Additional ConceptRoots can also be developed as IfcDoor, IfcSanitaryTerminal, etc.

Based on the set requirements to be developed, multiple concepts could be associated with ConceptRoot. For instance, for a property set named Pset_AccessibleBathroom, an mvd:Concept is created by specifying: applicableEntity="IfcSpace", (i.e., if the Bathroom space constraints is concerned, name="Pset_AccessibleBathroomConcept). Some could be standard additional to the custom Psets. This step will effectively link the Pset_AccessibleBathroom to every IfcSpace that is expected to be accessible for users. For custom Psets development, “Pset_AccessibleBathroom” includes new accessibility properties. This is where the actual numeric or Boolean requirements (slip resistance, turning diameters, adjacency) are stored.

Figure 4 shows an example of the interaction diagram that illustrates how IFC entities (such as IfcSpace), standard property sets (e.g., Pset_SpaceCommon), and custom property sets (e.g., Pset_AccessibleKitchen) are connected and convey the hierarchical nature of the MVD.

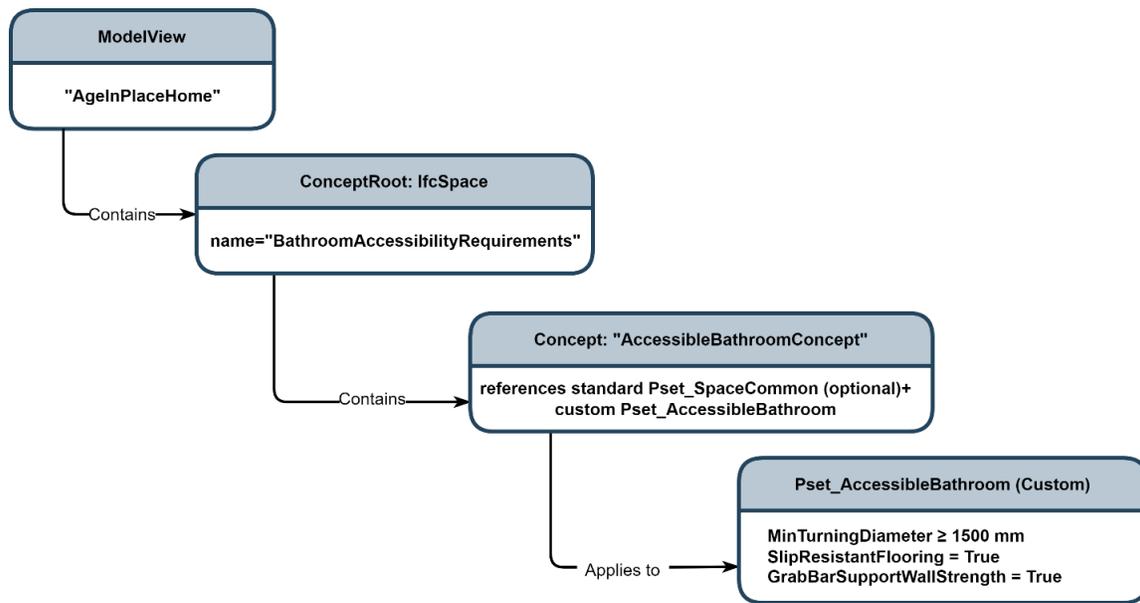


Figure 3: Example of MVD Structure for Accessible Bathroom Requirements

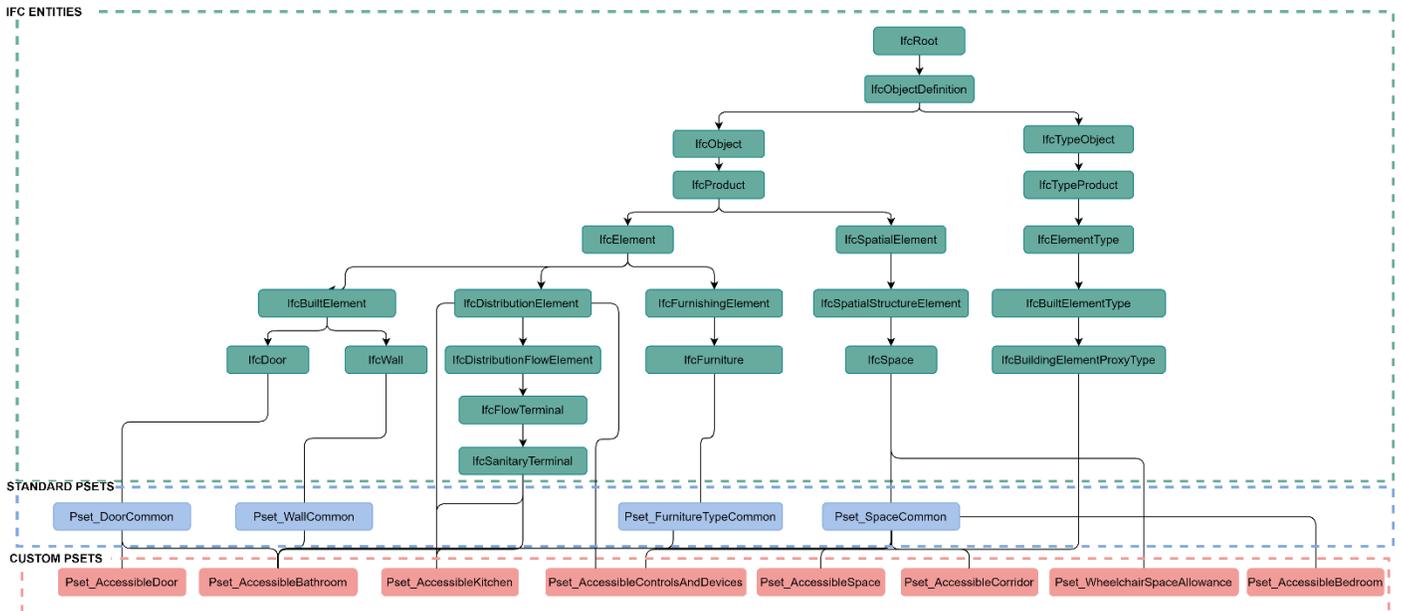


Figure 4: MVD interaction for AIPH design

6. CONCLUSION AND FUTURE WORK

This study presents a structured framework to integrate accessibility and Universal Design requirements into IFC-based BIM workflows. By going beyond simple property checks and capturing hierarchical,

relationship-driven rules (e.g., geometric clearances, adjacency constraints), specified in codes such as ISO 21542, it addresses the multifaceted nature of accessibility data. While the BuildingSMART International Information Delivery Specification (IDS) has recently reached a final standard specifically tailored for property-level checks, the MVD approach remains critical for scoping and structuring broader exchange requirements. In practice, MVD allows the framework to define which IFC entities and relationships must exist, while IDS or additional rule sets can further enforce numeric constraints, minimum/maximum values, and Boolean conditions on each property.

The proposed solution facilitates a software-neutral, OpenBIM workflow, making it feasible to embed accessibility data in an IFC-compliant manner, facilitating not only code compliance but also generative design and future integration with LCA. A key limitation is that the current research provides a conceptual framework rather than a fully validated model. Though prior works demonstrate feasibility for accessibility in BIM, a model testing is underway to sample interoperability in real design software (e.g., Revit), which will offer more direct insights into implementation challenges.

This framework forms the foundational base of our next phase, which aims to generate optimized floor plans for age-in-place homes at the conceptual design stage in an OpenBIM environment, focusing initially on new construction. Subsequently, we will examine how these methods can extend to analysis and model checking of existing buildings, where retrofits or renovations demand close coordination of new accessibility standards within older, potentially constrained structures. Furthermore, while ISO 21542 serves as a robust baseline, we will extend our approach to anticipate local or regional extensions, ensuring that teams can adapt the property sets to align with national or cultural codes.

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