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humantech

D2.5 - IFC schema extension

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Acronyms and definitions

Acronym	Meaning
2D/3D	Two/Three Dimensional
BCF	BIM Collaboration Format
BIM	Building Information Modeling
BIMxD	Extended Dynamic BIM
bSDD	builsingSmart Data Dictionary
HT	HumanTech
IDM	Information Delivery Manual
IDS	IDS Information Delivery Specification
IFC	Industry Foundation Classes
PC	Point Cloud
RGB-D	Red, Green, Blue plus Depth
ROS	Robot Operating System
UAV	Unmanned Aerial Vehicle
UC	Use Case
UGV	Unmanned Ground Vehicle
VR	Virtual Reality
WP	Work Package

Abstract

This deliverable, part of the HumanTech project, explores the integration of advanced technologies into BIM workflows through the extension of the Industry Foundation Classes (IFC) schema.

The document focuses on enriching the buildingSMART Data Dictionary (bSDD) with new classes, properties, and relationships, with specific attention to dynamic and portable construction entities such as robots.

It demonstrates mapping approaches to existing IFC entities and highlights gaps requiring future enhancements. The findings contribute to a more interoperable, flexible, and efficient digital construction ecosystem, aligning with the evolving demands of modern construction workflows.

Executive Summary

This deliverable, part of the HumanTech project, focuses on extending the Industry Foundation Classes (IFC) schema to better accommodate emerging technologies and dynamic construction processes. The document is structured into key chapters, each addressing specific aspects of the project's objectives.

Chapter 1 introduces the objectives of the deliverable, emphasizing the need for improved digital representation of temporary and portable devices, robotic systems, and related technologies within BIM workflows. The chapter provides an overview of the challenges associated with mapping these entities in the IFC schema.

Chapter 2 presents the methodology employed to identify gaps in the current IFC schema. It outlines the criteria for enriching the buildingSMART Data Dictionary (bSDD) with new classes, properties, and relationships while ensuring alignment with existing BIM standards.

Chapter 3 focuses on an exampl the Robot class as an example to demonstrate the proposed approach, that can be find in the online-published bSDD of the HumanTech project. The structure of Properties and Relationships of the entities are explored including the possible IFC extension and a new classe that can be add

Chapter 4 highlights proposed future enhancements to the IFC schema. These include the need to address the representation of dynamic and portable entities in construction workflows while maintaining interoperability and adaptability across global standards.

The HumanTech project

The European construction industry faces three major challenges: increase the safety and wellbeing of its workforce, improve its productivity, and become greener, making efficient use of resources.

To address these challenges, HumanTech proposes to develop **human-centred cutting-edge technologies** such as wearables for workers' safety and support and robots that can harmoniously coexist with human workers while contributing to the ecological transition of the sector.

HumanTech aims to achieve major advances in cutting-edge technologies that will enable a safe, rewarding, and digital work environment for a new generation of highly skilled construction workers and engineers.

These advances will include:

- **Robotic devices equipped with vision and intelligence** that allow them to navigate autonomously and safely in highly unstructured environments, collaborate with humans and dynamically update a semantic digital twin of the construction site in which they are.
- **Smart, unobtrusive workers protection and support equipment**. From exoskeletons activated by body sensors for posture and strain to wearable cameras and XR glasses that provide real-time workers' location and guidance for them to perform their tasks efficiently and accurately.
- An entirely new breed of **Dynamic Semantic Digital Twins (DSDTs) of construction sites** that simulate in detail the current state of a construction site at the geometric and semantic level, based on an extended Building Information Modelling (BIM) formulation that contains all relevant structural and semantic dimensions (BIMxD). BIMxDs will act as a common reference for all human workers, engineers, and autonomous machines.

The **HumanTech consortium** is formed by 22 organisations — leading research institutes and universities, innovative hi-tech SMEs, and large enterprises, construction groups and a construction SME representative — from 10 countries, bringing expertise in 11 different disciplines. The consortium is led by the German Research Center for Artificial Intelligence’s Augmented Vision department.

Contents

1. Introduction

Expanding existing standards within the construction sector plays a pivotal role in effectively managing both construction and demolition phases, as underscored in the HumanTech project. This endeavour encompasses the integration of comprehensive data concerning robotic elements, encompassing their qualitative and quantitative attributes. Of particular significance is the seamless integration of this data into HumanTech's BIMxD platform. This strategic approach, meticulously cultivated in the project's Work Package 2 (WP2), involves an in-depth analysis of the current state of openBIM standards, coupled with their augmentation to enhance comprehensibility across diverse stakeholders within the construction domain.

Standardization and harmonization of this enriched data hold paramount importance, serving as the linchpin for optimizing the synergy between robots and human workers within Building Information Modeling (BIM) processes. This harmonious integration promises to propel the construction sector towards significant advancements in innovation and modernization, ultimately reshaping the industry's landscape.

1.1. Interoperability

The term "interoperability" refers to the ability of different systems, networks, devices, applications, or components to exchange and utilize information. It plays a fundamental role in Building Information Modeling (BIM), allowing the integration of both geometric and descriptive data initially defined in BIM authoring software into various workflow processes, aligning with specific model uses and objectives.

Interoperability addresses three vital technical requirements. Firstly, it facilitates information exchange among diverse stakeholders during project phases, like the design phase where architects and engineers contribute data for quantity estimation. Secondly, it ensures the continuous use of information throughout project stages, spanning from initial design to demolition. Thirdly, it enables access to archived data throughout an asset's lifecycle, even when the original software is obsolete.

In an age of increasing specialization among stakeholders, there is a risk of fragmented information exchange. However, digital technologies offer the potential to streamline these exchanges, enhance expertise, and simplify communication. Traditional project and management communication methods have been replaced by software tools, which have faced communication limitations, resulting in what's been referred to as the "Island of Automation" since the 1990s.

1.2. The Concept of OpenBIM

In the dynamic realm of construction and infrastructure development, effective specialization demands adaptability and a shared vision to overcome potential challenges. What commenced as a modest endeavor in product and process modeling has since evolved into a sweeping concept that transcends traditional Building Information Modeling (BIM). Today, BIM serves as the bedrock for what is now termed the Digital Twin of the built environment, a pivotal element within the framework of Industry 4.0.

To facilitate interoperable public information services across the European Union, an extensive interoperability framework has been established, encompassing four layers: legal, organizational, semantic, and technical. In this specific context, each of these layers plays a crucial role in shaping BIM methodology and its ongoing evolution. Legal considerations revolve around the legislative landscape in different states, indirectly influencing operational aspects governed by organizational, semantic, and technical levels. Organizational layers provide clarity on how information requests are exchanged among service providers, delineating responsibilities and expectations. Semantic layers ensure the meaningful interpretation of data and semantic information through well-defined concepts (entities, properties, etc.) and their relationships, facilitated by the use of ontologies (data dictionary bSDD). These semantic considerations are intricately connected to technical standards, which dictate data structures for entities, geometries, associated properties, and classifications, thereby ensuring seamless object-based data exchange.

In the ever-evolving landscape of construction and infrastructure development, the adoption of innovative technologies is imperative for maintaining a competitive edge, mitigating risks, and ensuring the successful execution of projects. One such innovation that has gained substantial traction in recent years is openBIM, a paradigm shift that is revolutionizing our approach to Building Information Modeling (BIM) and data management within the AECO (Architecture, Engineering, Construction, and Operations) industry.

OpenBIM, short for "Open Building Information Modeling," represents a fundamental departure from the traditional closed BIM methodologies that have held sway in the industry for decades. At its core, openBIM embodies a collaborative, standards-based approach to designing, constructing, and managing building and infrastructure projects. It places a premium on the use of open standards and formats, ensuring that data is not confined to a single proprietary software or platform. Instead, it facilitates eamless data exchange among different BIM software applications, fostering greater interoperability and mitigating the risk of data silos.

1.2.1. Key Differences from Closed BIM

To fully appreciate the significance of openBIM, it's essential to contrast it with closed or proprietary BIM approaches:

Vendor Neutrality: Closed BIM solutions often tie users to a specific software vendor, limiting flexibility and collaboration. In contrast, openBIM encourages vendor neutrality, enabling project stakeholders to select the best software tools for their specific tasks while maintaining data compatibility.

Interoperability: Closed BIM systems struggle with interoperability issues, making it challenging to share and integrate data with external parties. openBIM prioritizes interoperability, allowing various stakeholders to work together seamlessly, regardless of the software they use.

Data Transparency: openBIM promotes data transparency throughout a project's lifecycle. Unlike closed BIM systems, where information can be locked within proprietary formats, openBIM ensures that project data remains accessible and transparent, fostering better decision-making and risk management.

Collaboration: Closed BIM often creates information silos, hindering collaboration among architects, engineers, contractors, and facility managers. openBIM breaks down these silos, facilitating real-time collaboration and reducing errors, which can result in cost and time savings.

Long-Term Viability: Closed BIM solutions may face obsolescence as software providers evolve or discontinue their products. openBIM, rooted in open standards, offers greater assurance of long-term viability and adaptability.

1.2.2. Benefits of openBIM

The adoption of openBIM brings a multitude of benefits to construction and infrastructure projects:

Enhanced Collaboration: openBIM encourages multidisciplinary collaboration, enabling project stakeholders to work together seamlessly, leading to improved project coordination and communication.

Reduced Errors and Rework: By ensuring data consistency and transparency, openBIM helps in identifying and resolving issues early in the design and construction phases, reducing costly errors and rework.

Improved Data Accessibility: With data stored in open formats, project data remains accessible and adaptable throughout the project's lifecycle, supporting efficient facility management and maintenance.

Flexibility in Software Choices: openBIM allows organizations to select software tools that best suit their needs and budget, eliminating vendor lock-in and fostering innovation.

Cost and Time Savings: By streamlining processes, minimizing errors, and improving collaboration, openBIM can lead to significant cost and time savings on construction and infrastructure projects.

2. OpenBIM Standards

2.1. buildingSmart's OpenBIM Standards

As mentioned earlier, BIM models for infrastructure must be exchanged using open formats. The main reasons for this are summarized below:

- Often, these are public works, the first to be involved in the legislative process, also regarding the contractual base amount.
- The BIM experience, partly inherited from buildings, reveals that an information exchange hierarchy based on open standards is more effective and productive over time.

The ISO 16739 standard defines Industry Foundation Classes (IFC) as the international standard for achieving open information exchange within BIM processes. IFC is a data model that aims to revolutionize the construction industry by transferring Information Technology techniques, with a particular focus on databases. The same processes that generated it are still ongoing, allowing IFC to be seen as a constantly changing and expanding universe, as seen in the infrastructure domain between 2018 and 2021 (bridges, roads, railways, ports), and for the development of other infrastructures (airports, tunnels) in the coming years, enabling a more comprehensive description of the built environment.

2.1.1. Key OpenBIM Standards

However, the mere definition of a data model does not fulfil the needs of a complex industrial sector like construction. For this reason, buildingSmart International articulates its information standard into five key OpenBIM standards plus two emerging standards:

- **Industry Foundation Classes (IFC)**

  At the core of buildingSMART's standards lies the **Industry Foundation Classes (IFC)**, defined by ISO 16739. IFC serves as an open data model enabling seamless information exchange throughout the lifecycle of a project. It provides a universal format for BIM data and supports integration across various domains, including buildings, infrastructure, and cultural heritage. Notably, IFC is a living standard, with recent advancements addressing infrastructure domains such as bridges, roads, and ports, and future extensions planned for airports and tunnels.

- **Model View Definition (MVD)**

  To ensure tailored information exchange, **Model View Definition (MVD)** specifies subsets of IFC data models for particular use cases. This targeted approach ensures data relevance and precision for diverse project requirements. It has a huge relevance once considering the older version of IFC (IFC 2x3 and IFC4 ADD2) because it has a large impact on the quality of the data exported.

- **buildingSMART Data Dictionary (bSDD)**

  The **buildingSMART Data Dictionary (bSDD)** is a centralized repository defining and standardizing properties, classifications, and terminologies used across BIM workflows. It enhances consistency and understanding by providing universally recognized property definitions. It would be in the future the logic in which the IFC standards can be improved and extended, as it has been proposed in the HumanTech project.

- **Information Delivery Manual (IDM)**

  The **Information Delivery Manual (IDM)** establishes standardized processes for defining information exchange requirements, streamlining communication between stakeholders and ensuring clarity in deliverables (**D2.1** in the HumanTech project).

- **BIM Collaboration Format (BCF)**

To facilitate the resolution of project issues, the **BIM Collaboration Format (BCF)** provides a standardized format for communicating product or process-related concerns. BCF enables seamless coordination among project teams by linking issue tracking with BIM models. The BIMxD platform is based on this protocol to exchange lot of information

The importance of having a standard available and the value of the cultural capital it conveys lead to the understanding that these tools should become a standard practice. They can be easily implemented in private company workflows, even with proprietary platforms.

2.1.2. Emerging Standards

In addition to these established pillars, buildingSMART is actively developing new standards to address evolving needs:

- **Information Delivery Specification (IDS)**

IDS is designed to define specific informational exchange requirements, enabling their computational interpretation. This approach ensures precision and reliability in meeting project-specific data needs. An IDS is provided as attachment of this deliverable for the Humantech Project.

- **openCDE APIs**
- The **openCDE APIs** aim to enhance interoperability by standardizing Application Programming Interfaces (APIs) within Common Data Environments (CDEs). This innovation fosters seamless collaboration across platforms and ecosystems in the AEC sector. The BIMxD platform is based on this protocols (Deliverable **D2.3**).

2.1.3. Services Supporting openBIM Standards

buildingSMART also provides supporting services, such as:

- **Validation Services**

These services ensure adherence to openBIM standards by verifying the quality and compliance of BIM workflows and tools.

- **Use Case Management (UCM)**

UCM facilitates the definition and customization of exchange scenarios specified in IDM, enabling tailored solutions for diverse projects.

- **Professional and Software Certification**

buildingSMART offers certifications to validate the competency of professionals and the compliance of software tools with openBIM standards.

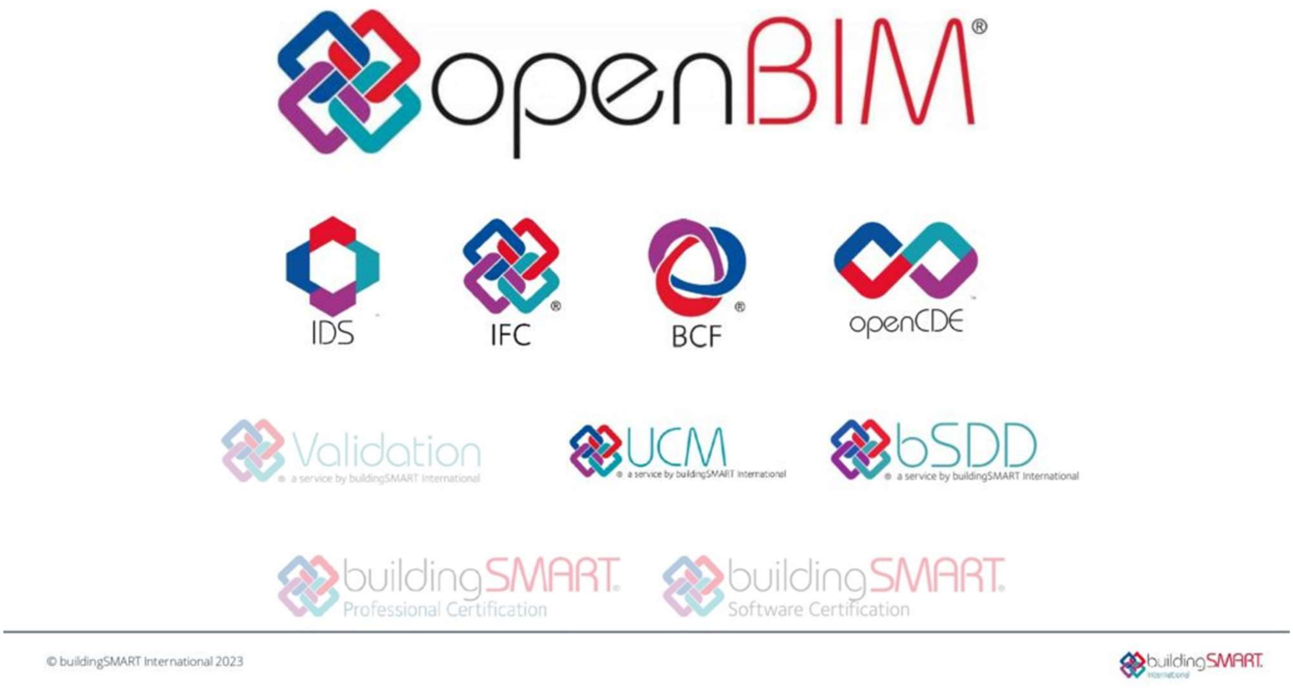

Figure 1 Organization of standards developed by buildingSmart International. (Adapted from buildingSmart Int)

2.2. The Standardization Process for Interoperability

The first aspect of standardization is achieved through a breakdown of processes that allow the description of specific information exchanges occurring in the construction industry. To adequately translate the IFC data model into individual activities and to facilitate and make the implementation and management of the same data model in various software applications in the construction industry more sustainable, two standards have been implemented in the previous deliverable, these are IDM to define the minimum rules for documenting information exchange between at least two software applications (Deliverable **D2.1**).

2.2.1. IDS as

In the three years since the inception of the HT project, significant advancements have shaped the openBIM ecosystem. These changes reflect both the evolution of buildingSMART standards and the increasing complexity of implementing openBIM in practice. To align with these advancements, the team has decided to include considerations on the Information Delivery Specification (IDS) as an applicable implementation of the proposed IFC extensions.

OpenBIM standards have undergone rapid development to address the growing demands of the AEC industry. Building on the foundational pillars of openBIM—IFC, bSDD, BCF, IDM, and MVD—the recent focus has been on refining interoperability and data accuracy for multiple AEC projects. The extension of IFC standards, particularly for infrastructure domains such as bridges, tunnels, railways, and ports, underscores the dynamic nature of openBIM.

While these developments enrich the applicability of openBIM standards, they also highlight the need for precise, computationally interpretable mechanisms to define and exchange project-specific information. This is where IDS emerges as a transformative tool.

The Information Delivery Specification (IDS) is a pivotal standard introduced to address the challenges of defining and validating information exchange requirements in an increasingly complex openBIM environment. IDS allows stakeholders to define specific informational needs, ensuring that they are both unambiguous and computationally interpretable. This capability aligns with the ongoing IFC extensions, facilitating their practical implementation.

To address this complexity for both users and software companies, and considering the growing need, driven by increasingly extensive projects and specialization of stakeholders, to define specific informational requirements, buildingSMART is developing the aforementioned Information Delivery Specifications (IDS). IDS is a collection of specifications designed to link a specific informational requirement to a verifiable and applicable condition. If the condition is not met or incomplete, the requirement is ignored. The connection with other standards, both IFC and bSDD, allows for the customization of information exchange.

IDS defines informational exchanges as follows:

*"**All entities X (of class/type Y), having attribute/classification/property/material Z,** must have attribute/class/classification/property/material/type (…) and/or be part of (…)."*

The first part of the specification (in bold and Italic) is the context in which the specification must be met, while the blue part determines the requirement. An example of a specification is as follows:

*"**All pile stems with ObjectType .PIERSTEM.** must have an IfcPropertySingleValue property named 'Environmental Exposure Class' contained in the custom property set 'P_Environmental.'"*

BCF

The BIM Collaboration Format (BCF) is used to facilitate communication among project stakeholders regarding issues, requests for clarification, and concerns that arise in connection with the BIM model. BCF associates a viewpoint and snapshot with descriptive data, involved parties, a responsible entity, and a deadline for resolution, all tied to a specific issue occurring within the model. This helps prevent inaccuracies and errors that may result from informal or text-based communication.

Once an issue is defined in BCF, the corresponding file (.bcfzip) is transferred from one user to another, edited, and then returned. BCF files can be "bounced" between multiple parties, as long as all parties maintain the integrity of the shared BCF file and do not distribute additional copies of it.

In addition to the file-based workflow, there is an API-based method using web services (RESTful) for BCF. This involves implementing a BCF server, which stores all BCF data and allows project participants to synchronize the creation, modification, and management of BCF topics in a centralized location.

IFC

The Industry Foundation Classes (IFC) is a data model used for the effective definition of a BIM (Building Information Modeling) project and the construction of a model that consistently represents the shape of the reference asset. It particularly focuses on ontological concepts, such as attribute inheritance, spatial and functional relationships, among others, within the scope of representation. The deterministic nature of the data model leads to the production of interoperable information models capable of shaping the asset's form while optimizing the quality of the final result based on the objectives to be met and how the model needs to be queried. Within the technical interoperability in BIM systems, where objects are central to the processes, whether they represent construction components or serve as references for management data (e.g., COBie), the definition of what and how information is exchanged forms the basis of openBIM standards.

The data model itself is known as IFC, which describes the geometry, attributes, and characteristics of objects while replicating real-world relationships. Its intention is to be applied to various domains within construction, expanding its coverage from building construction to many infrastructure domains, encompassing the entire lifecycle of the built asset. While initially, the IFC data schema was primarily used for architectural purposes, it has since been expanded to include various infrastructure domains such as bridges, roads, railways, and ports. The goal is to create a unified and shared standard that eliminates inconsistencies in the IFC schema, which was previously focused mainly on building construction. This aims to facilitate the exchange and understanding of shared information, ultimately aligning with fundamental sustainability principles to support a sustainability system.

However, it's essential to recognize that different infrastructure domains have inherent distinctions. Therefore, the approach to defining the data schema for a bridge, for example, differs from that of a road or port. While it's clear that the elements of the data model are ontologically distinguishable, it requires careful consideration and analysis to determine the logic of the model. This logic is derived from mechanical modeling, enabling the designer to break down the infrastructure into assembly objects or part objects, each with assigned geometric constraints, properties, manufacturing methods, calculation methods, and more. This same logic aims to apply to designers in each infrastructure domain.

The approach to be provided focuses on understanding shared dynamics that are applicable in multiple cases and those that require specific analysis. The latter will be detailed and exemplified concerning roads and, particularly, bridges.

The IFC standard structures the data schema with a lexicon and terms that have precise meanings and, consequently, specific behavioral actions within the data model itself. Some fundamental concepts include:

- Entity: Represents any concept, abstract or concrete, characterized by constraints and attributes.
- Attribute: The minimum unit of information for each entity.

- Instance: The materialization, either physical or abstract, in the digital model of a specific entity. It represents one of the objects in the exported model and is synonymous with occurrence.
- Property: A unit of information associated with each instance.

In addition to these concepts, there is the notion of a concept template, which represents how IFC operates within the scenarios of BIM model usage. It connects the class to key themes (typification methods, aggregation methods, association with a geometric representation, etc.) to ensure functional-spatial, performance, and geometric description.

bSDD

The BuildingSMART Data Dictionary (bSDD) is a comprehensive and standardized terminology and data classification system used within the field of Building Information Modeling (BIM) and construction industry. It provides a structured and organized framework for defining and managing data associated with construction projects and built assets. The bSDD serves as a common language that facilitates effective communication and data exchange among various stakeholders involved in the construction and building management processes.

2.3. bSDD and IDS to easily extend the IFC data model

At the core of the digital revolution in the AEC field driven by BIM processes, IFC serves as the common language for representing and exchanging information related to construction projects. However, over the years, IFC has demonstrated limitations in usability and applicability in specific situations, such as intelligent construction sites. To address these challenges, in the three years since the inception of the HT project, there has been a push toward integrating tools like the buildingSMART Data Dictionary (bSDD) and the Information Delivery Specification (IDS). These tools provide a more immediate and targeted solution compared to initiating a new project to extend the IFC domain, which often involves lengthy implementation periods and significant bureaucratic requirements.

The bSDD supports greater clarity and precision in data representation through a standardized vocabulary tailored to project needs. This ensures consistent terminology usage across workflows, reducing ambiguity and the potential for misinterpretation. By integrating with IFC, bSDD enhances interoperability between different BIM software applications, allowing them to share a common understanding of data semantics. This structured approach also facilitates efficient data organization, retrieval, and management, supporting streamlined and more productive workflows. Additionally, standardized rules and relationships between data elements contribute to data integrity throughout the project lifecycle, minimizing discrepancies and improving outcomes.

The IDS, on the other hand, provides a structured framework for defining and validating project-specific information exchange requirements. By linking informational needs to verifiable conditions, IDS ensures that exchanges meet both technical and functional criteria. It allows for granular control over how data is prepared and shared, reducing errors and improving reliability. The ability to integrate IDS with IFC and bSDD further strengthens its utility, enabling targeted extensions of the IFC schema without requiring significant revisions. Together, these tools provide practical pathways for addressing current challenges in BIM interoperability while supporting more precise and standardized information workflows.

3. Bridging the Gap: Addressing Limitations in OpenBIM Standards

3.1. The actual situation of openBIM

Notable limitation exists in the current OpenBIM standards, particularly in the prevailing practice of exporting authored BIM models into IFC (Industry Foundation Classes). The activities of the WP2 and in particularly of the task T2.4 delves into the identified lack of bidirectional communication, the absence of integration with robotic technologies and in the workflows that involved them, highlighting the need for industry-wide improvements. Following some of the most challenging difficulties are highlighted:

Addressing Misconceptions: OpenBIM Beyond IFC Export: Some users may mistakenly perceive openBIM as merely exporting IFC files, overlooking the broader collaborative standards. openBIM encompasses a range of interoperability standards beyond IFC, promoting bidirectional data exchange and interconnected workflows for real-time collaboration throughout the project lifecycle. Embracing these comprehensive standards, such as bSDD and others, goes beyond exporting and unlocks the full potential of openBIM, fostering efficiency, accuracy, and improved project outcomes. Educating users about the holistic nature of OpenBIM encourages a more informed and collaborative approach within the architecture, engineering, and construction industry.

Robotic Technologies and IFC Standards: A significant gap exists in OpenBIM regarding the integration of robotic technologies with Industry Foundation Classes (IFC) standards, hindering the industry from fully capitalizing on the efficiency and innovation that robotics can bring to construction processes. The lack of mutual understanding between the robotic side and IFC standards poses challenges in seamless collaboration. Bridging this knowledge gap is essential to unlock the potential of automation, enabling more precise, faster, and adaptable construction workflows. Collaboration between the robotics and AEC communities is crucial for developing standards that accommodate the specific requirements of robotic technologies while ensuring interoperability in the construction sector. Closing this gap is imperative for fostering a more cohesive and advanced construction ecosystem, and the aim is to starts from the HumanTech results and products.

Transformation of IFC Standards: The IFC standards have evolved over the years, with versions now official IFC 2x3, IFC 4ADD2, and IFC 4.3 progressively implementing and expanding the descriptions of building elements. Despite these advancements, a substantial number of practitioners continue to use the outdated IFC 2x3 standard. This practice implies that many in the industry are adhering to standards that may not fully capture the intricacies of modern AEC construction requirements. The latest IFC version stands as a testament to the exhaustive description of building elements within the OpenBIM framework. However, the industry must actively engage with and adopt these latest standards to ensure that projects are represented accurately and comprehensively. Encouraging the widespread use of the most recent IFC standards will contribute to a more standardized, interoperable, and future-proof OpenBIM ecosystem.

Name	ISO publication	Current Status	EXPRESS	XSD	OWL HTML	RDF
IFC 4.3 ADD2	ISO 16739-1:2024	Official	EXP	XSD	ifcOWL	- (TTL)
IFC4 ADD2 TC1	ISO 16739-1:2018	Official	EXP	IFC4.xsd	ifcOWL IFC4 ADD2 TC1	RDF

Name	ISO publication	Current Status	EXPRESS	XSD	OWL HTML	RDF
IFC2x3 TC1	ISO/PAS 16739:2005	Official	EXP	IFC2X3.xsd	ifcOWL IFC2x3 TC1	RDF

IFC file extension: The format predominantly used for sharing IFC is the EXPRESS file, with other formats being adopted to a lesser extent. This implies a lower dissemination of information within the model, as the EXPRESS file is the prevailing method of sharing. The predominant choice of this format might limit the accessibility and widespread sharing of data, as some users may not be able to interpret or use less commonly adopted formats. Exploring different formatting options could promote greater interoperability and information sharing within the OpenBIM ecosystem.

The ongoing technical changes in buildingSMART's standards and services are undeniably crucial, yet they present significant challenges for those tasked with implementing and adapting to them. These updates are vital for advancing the efficiency, interoperability, and sustainability of construction projects, signifying a progressive step in the AEC industry. However, the transition to these enhanced standards, such as the updated IFC, bSDD and IDS demands a considerable investment in terms of training, software upgrades, and changes to existing workflows.

Addressing the limitations in OpenBIM standards requires a collective effort from industry stakeholders. By promoting bidirectional communication, integrating robotic technologies, and advocating for the adoption of the latest IFC standards, the AEC sector can usher in a new era of collaborative and technologically advanced practices. It is crucial for professionals to stay informed and embrace evolving standards to fully unlock the potential of OpenBIM in shaping the future of construction.

3.2. IFC 5 the future of openBIM

IFC 5 represents the next iteration of the Industry Foundation Classes, focusing on addressing technical gaps and expanding its applicability to meet the evolving needs of the construction and infrastructure sectors. One of the key enhancements in IFC 5 is improved support for dynamic data workflows, enabling better integration with modern technologies such as IoT devices, sensor networks, and real-time data systems. This is achieved through the introduction of more granular data structures and the refinement of existing schemas to accommodate detailed and accurate data exchange across disciplines.

IFC 5 also introduces greater modularity in its schema, allowing for domain-specific extensions while maintaining consistency with the core standard. This modularity simplifies the adaptation of IFC to niche applications, such as intelligent construction sites or advanced infrastructure management, without requiring significant overhauls to the entire schema. Additionally, improvements in the representation of complex geometries, advanced material definitions, and construction methods address some of the limitations identified in earlier versions.

Another important focus of IFC 5 is enhancing its compatibility with emerging standards, such as the Information Delivery Specification (IDS) and Common Data Environment (CDE) APIs, to support more streamlined and automated information workflows. These improvements are aimed at reducing ambiguities in data interpretation and increasing the accuracy of information exchanges across the lifecycle of built assets, from design through operation and maintenance. By refining both its scope and technical implementation, IFC 5 aims to provide a more robust framework for interoperability in increasingly complex and multidisciplinary projects.

4. HumanTech and openBIM standards

The HumanTech project addresses a distinct challenge: engaging with the construction industry to harmonize requirements across various phases, particularly in the development of BIM models and digital surveys. A primary goal is to bridge these needs with advancements in robotics and human-centric activities. To enable the adoption and adaptability of HumanTech project outcomes beyond its immediate context and across diverse workflows, adherence to standardized protocols is necessary. This is achieved through the application of openBIM standards, with a focus on developing a specialized dictionary within the buildingSMART Data Dictionary (bSDD).

At the link provided below you can find the bSDD of the HumanTech project published with the entire development of the IFC extension proposal.

https://search.bsdd.buildingsmart.org/uri/LIMlab/HT

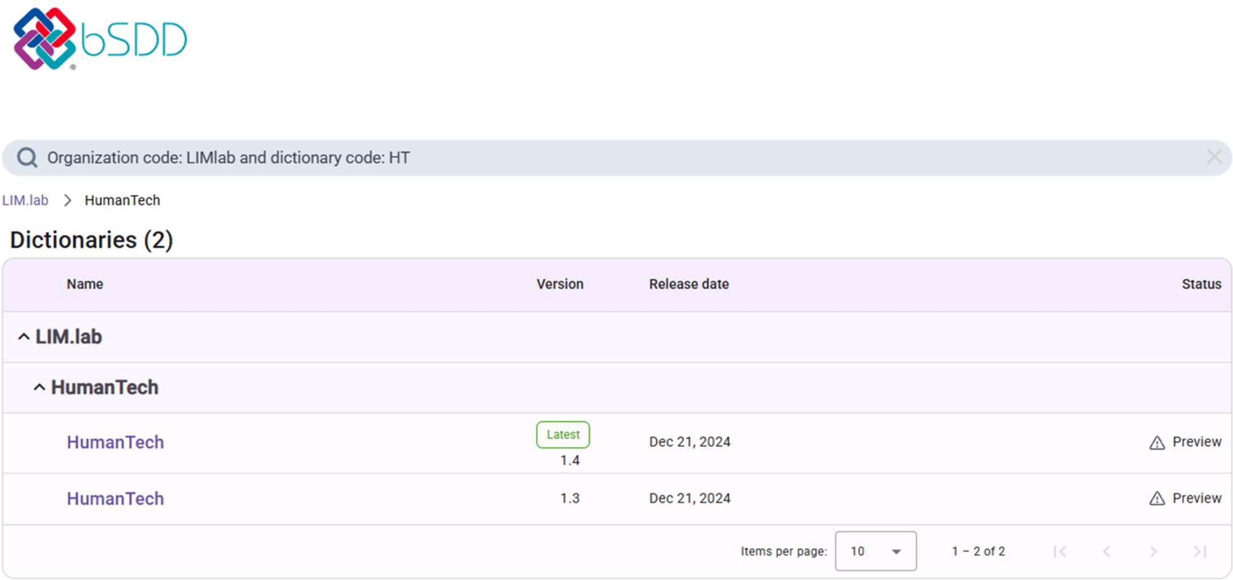

Figure 2 First Page of the HumanTech bSDD where is possible to explore the proposed IFC extension, and the different review of the entities added.

This tailored dictionary is designed to comprehensively capture and organize object descriptions, including their specific attributes and their connections to the construction model within the IFC schema. Additionally, it specifies relationships between objects and other entities on the construction site, ensuring alignment with openBIM principles. By adhering to these standards, the dictionary facilitates clear communication and semantic consistency across various construction workflows and tools.

Through an analysis of buildingSMART products, strategic implementation methodologies have been established to ensure the seamless integration of these components into the project framework. This approach ensures that the tools and processes developed in the HumanTech project remain interoperable and scalable, aligning with industry standards while supporting innovative applications in construction, robotics, and human-centered design.

Five are the main topics in the Hamantechh project that has to be expanded and integrated in the IFC and larger openBIM. These are markers, workers, robots, mission plannings, falling hazards. This comprehensive strategy is not just about incorporating new elements into the bSDD; it's about redefining and enhancing the way the robotic in construction industry operates, using the principles of digital transformation and standardization.

Robots and Automated Systems: Enhancing the previous translation, it's important to emphasize the role of robots in the modern construction landscape and the necessity for their detailed categorization in the HT bSDD. This categorization not only aids in identifying different types of robots but also in understanding their unique capabilities and limitations. By doing so, the HT bSDD can facilitate more effective deployment of robotic technology, optimizing tasks ranging from simple material handling to complex construction processes, and ensuring seamless integration into existing construction workflows. This approach represents a significant step towards a more automated and efficient construction industry, where robots play a key role in various stages of building and demolition processes.

Digital Survey Markers are more than mere physical reference points in a digital survey. They are conceptualized as data-rich elements capable of interacting with digital models and real-world coordinates. These markers facilitate a precise alignment between digital plans and physical construction, effectively bridging the gap between virtual designs and their real-world execution. Such integration ensures a high level of accuracy and efficiency in transforming designs into tangible structures. Building on the foundation laid by CWA 18046:2023, which provided a standardized approach for using markers on-site, the next step involves translating these standards into the bsDD format. This transformation is crucial for enhancing the utility and effectiveness of markers in modern construction projects.

Workers: Although the Industry Foundation Classes (IFC) framework allows for the description of intangible objects, this feature is not widely utilized in standard practices. The aim, therefore, in the HT bSDD, is to comprehensively describe the various professional roles active on construction sites. This detailed characterization will facilitate their recognition in processes such as reconstruction, demolition, and in their interactions with robots on the BIMxD platform. By doing so, it enhances the practical application and relevance of non-material object descriptions in the construction industry.

Areas (mission plannings, falling hazards, etc.): Another group of terms that need to be implemented within the bsDD concerns the ares where different types of activities can be performed. In partucikary 'mission planning area,' in the context of automating area scanning of built assets using UGV. A precise description of these areas with specific and standardised characteristics is essential for accurate representation on the BIMxD platform. Moreover, these descriptions should be versatile enough to be reused in other projects where digital surveys are closely tied to the BIM model. This implementation will facilitate more efficient and precise planning and execution of construction projects, leveraging advanced drone technology for comprehensive area analysis and integration with BIM processes. In the context of the HT bsDD, it's crucial to implement terms that address the risks associated with falling hazards in construction sites. This includes defining areas prone to such hazards, missing part in the construction elements specifying safety protocols, and delineating preventive measures in the BIMxD platform. Accurate and standardized descriptions of these risk zones are essential for ensuring the safety of workers and for facilitating the integration of these safety measures into the BIMxD platform. This effort aims to enhance the planning and execution of construction projects by prioritizing safety, particularly in high-risk environments.

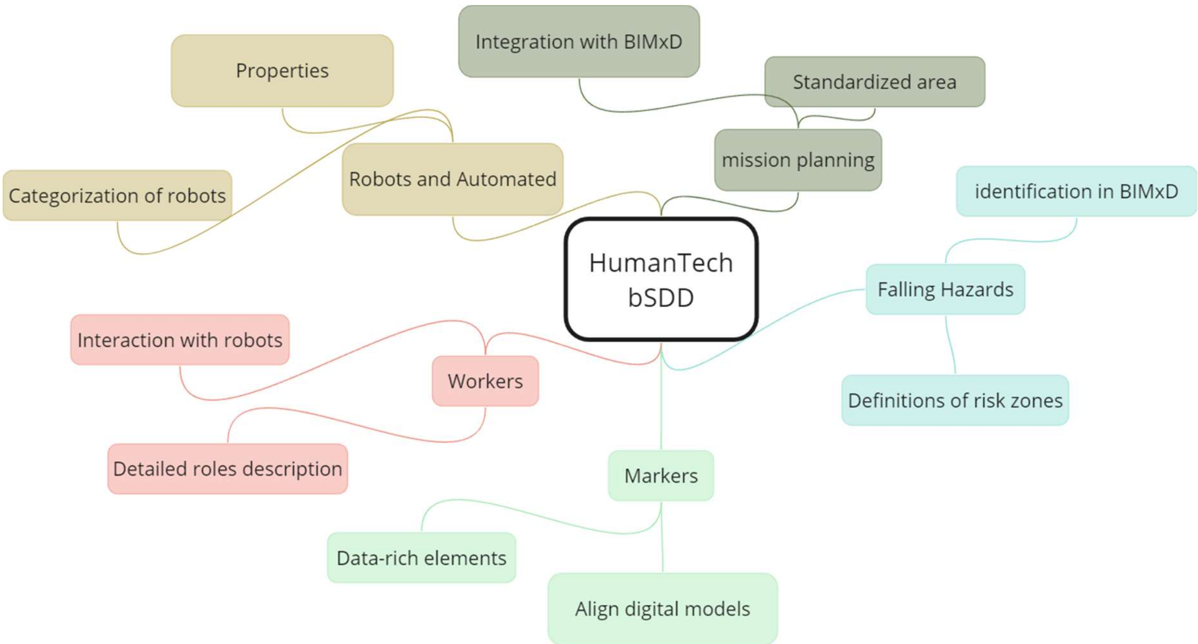

Figure 3 Schema of the terms that needs to be enriched in the Humant Tech bSDD to expand the IFC schema

The bsDD was enriched with multiple classes, properties, and relationships between objects, along with mappings to IFC classes. This report identifies potential classes that could be added to the IFC domain in the future.

Using the Robot class as an example, the approach is explained in detail. Additional references can be identified by directly navigating the provided link.

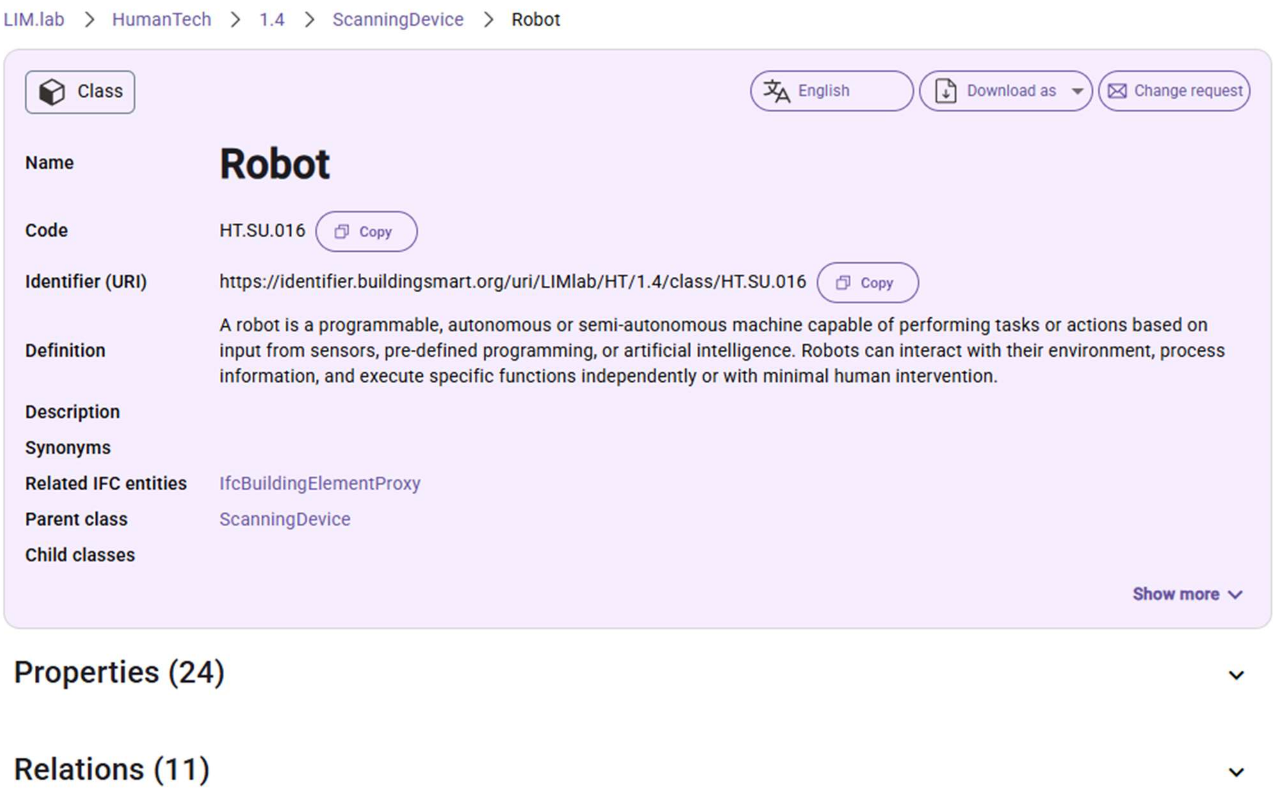

Figure 4 example of the Robot entities in bSDD that contains the following characteristics

Field	Value
Code	HT.SU.016
Name	Robot
ClassType	Class
Definition	A robot is a programmable, autonomous or semi-autonomous machine capable of performing tasks or actions based on input from sensors, pre-defined programming, or artificial intelligence. Robots can interact with their environment, process information, and execute specific functions independently or with minimal human intervention.
Description	A Robot class within the bsDD domain represents intelligent machines designed to perform specific tasks autonomously or semi-autonomously. These machines are integral in automation, manufacturing, and various industries, enhancing precision and efficiency.
ParentClassCode	HT.SU.01
RelatedIfcEntityNamesList	IfcBuildingElementProxy
Synonyms	null
ActivationDateUtc	2024-02-01 T00:00:00
ReferenceCode	null

CountriesOfUse	AD, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, FI, FR, FO, GG, GR, HR, HU, IE, IM, IS, IT, JE, LI, LT, LU, LV, MC, MD, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, UA, GB, JP
CountryOfOrigin	IT
CreatorLanguageIsoCode	EN

Table 1 Example of the attributes and the values of the entity "Robot"

In particular, attention is given to the IFC mapping of the object. For example, a Robot can be mapped as an *IfcConstructionEquipmentResource* using a *PredefinedType* from the list

DEMOLISHING	Removal or destruction of building elements.
EARTHMOVING	Excavating, filling, or contouring earth.
ERECTING	Lifting, positioning, and placing elements.
HEATING	Temporary heat to support construction.
LIGHTING	Temporary lighting to support construction.
PAVING	Roads or walkways such as asphalt or concrete.
PUMPING	Installing materials through pumps.
TRANSPORTING	Transporting products or materials.
USERDEFINED	User-defined resource.
NOTDEFINED	Undefined resource.

If USERDEFINED is used, the *ObjectType* can be specified as *SURVEYING* when the robot is used to perform a digital survey of the area.

Suggestion for IFC Integration

To improve IFC integration, it is suggested to create a new class as a subclass of *IfcElement,* called *IfcPortableDevice*. This class would include all objects that are movable and temporary on the construction site. Such objects are associated with temporary activities that frequently change over time and can move across the *construction area. This addition would provide better representation and management* of portable and temporary devices, such as robots, within the IFC schema.

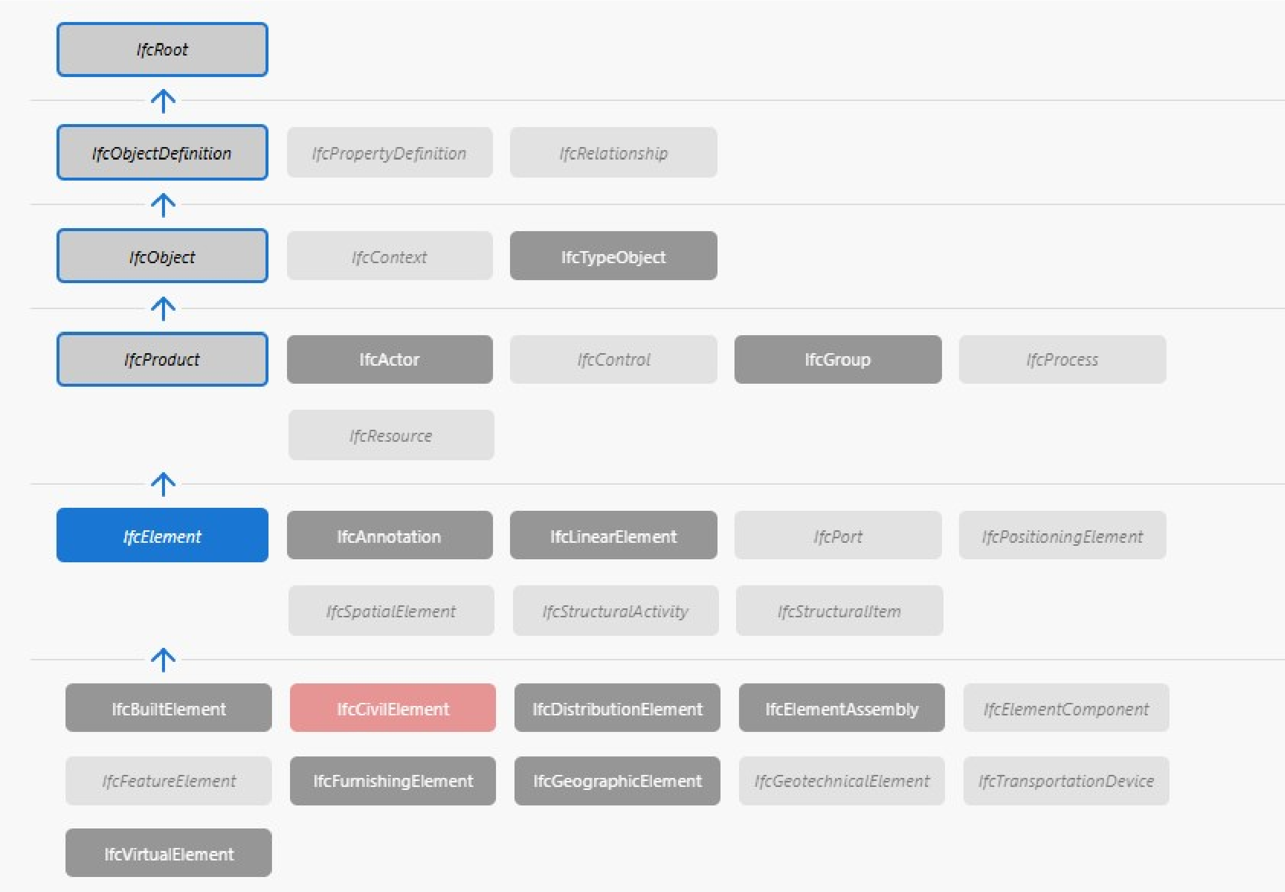

Figure 5 Possible superclass inheritance for the proposed IfcPortableDevice as a new IFC class to map entities such as the Robot

The following tables provide a detailed overview of the Robot class within the bsDD framework. The first table outlines the properties of the Robot class, describing its key attributes such as dimensions, payload capacity, power specifications, and operational capabilities. These properties ensure a comprehensive understanding of the robot's functionality and application scope. Moreover, they are organise in Set of properties in order to group them rationally.

The second table highlights the relationships of the Robot class with other entities and components. These relationships define how the Robot interacts with or integrates components like sensors, cameras, and scanning systems. The connections also indicate compatibility with advanced technologies such as laser scanning and photogrammetry.

Similar information is available for other entities related to the HumanTech project, which are usable in BIM-based projects through the BIMxD platform. These tables collectively demonstrate the Robot class's capabilities, interoperability, and relevance within digital construction and automation domains.

Property Code	Name	Definition	Description	Data Type	Units
HT.SU.P.21	Size	The physical size of the device.	Dimensions of the robot.	Real	mm
HT.SU.P.31	Width	The physical width of the device.	Width dimensions of the robot.	Real	mm
HT.SU.P.32	Height	The physical height of the device.	Height dimensions of the robot.	Real	mm
HT.SU.P.22	PayloadCapacity	The weight the robot can carry.	Influences payload capacity and performance.	Real	g
HT.SU.P.24	IngressProtection	Resistance against dust and water.	Expressed as an IP rating.	String	
HT.SU.P.33	MobilityDegrees	Degrees of movement freedom.	Number of independent movements the device can perform.	Real	°
HT.SU.P.34	MaximumIncline	Maximum angle the robot can climb.	Determines movement over steep surfaces.	Real	%
HT.SU.P.35	ObstacleDetection	The robot's ability to detect obstacles.	Enhances safety and navigation.	Real	N
HT.SU.P.16	BatteryCapacity	The total energy storage capacity.	Measured in milliampere-hours or watt-hours.	Real	mAh
HT.SU.P.18	ChargingTime	Time required for a full charge.	Based on charger and battery type.	Real	min
HT.SU.P.20	PowerSource	Type of energy source used by the robot.	Enhances operational flexibility.	String	
HT.SU.P.40	Autonomy	Ability to perform tasks autonomously.	Determines automation capabilities.	Boolean	
HT.SU.P.41	RemoteOperation	Whether the robot can be operated remotely.	Indicates operational range.	Boolean	
HT.SU.P.42	CommunicationInterfaces	Supported communication protocols.	Describes connectivity standards (e.g., Wi-Fi, Bluetooth).	String	

Table 2 Example of the properties related to the "Robot" entity in the bSDD

Properties (24)

Filter properties

Name	Data type	Units	Definition	Dictionary	Identifier (URI)
SetP_Battery-Power					
BatteryCapacity	Real	mAh	The energy storage capacity of the device's battery.	HumanTech	
ChargingTime	Real	min	The time needed to fully charge the device's battery.	HumanTech	
BatterySwappability	Boolean		Whether the battery can be easily swapped mid-operation.	HumanTech	
PowerSourceType	String		The type of power used by the device (e.g., battery, AC).	HumanTech	
SetP_Communication					
ConnectivityOptions	String		The communication interfaces supported by the device.	HumanTech	
TransmissionRange	Real	m	The maximum distance the device can communicate with the controller.	HumanTech	
LiveVideoFeed	Boolean		Whether the device can transmit live video to the controller.	HumanTech	

Figure 6 Example of the properties related to the entity "Robot" organised in Set of Properties

Relation Type	Related Class Name	Description
HasPart	TerrestrialLaserScanner	Indicates the robot contains a terrestrial laser scanning component.
HasPart	Camera	Specifies that the robot may include a camera for imaging or sensing.
HasPart	GNSSSensor	Links the robot to GNSS sensors for navigation and positioning.
HasPart	MobileHandheldScanner	Identifies integration with handheld scanning systems.
HasReference	TerrestrialPhotogrammetry	References related photogrammetric techniques applicable to the robot.
HasReference	MobileLaserScanning	Suggests compatibility with mobile laser scanning systems.

Table 3 Example of the relationship related to the "Robot" entity in the bSDD

Relations (11)

Filter relations

Relates with	Direction	Identifier (URI) of related class	Type	Dictionary	Version/Status
TerrestrialLaserScanner	Intern	.../uri/LIMlab/HT/1.4/class/HT.SU.011	HasPart	HumanTech	1.4 Preview
Camera	Intern	.../uri/LIMlab/HT/1.4/class/HT.SU.013	HasPart	HumanTech	1.4 Preview
MobileHandheldScanner	Intern	.../uri/LIMlab/HT/1.4/class/HT.SU.015	HasPart	HumanTech	1.4 Preview
GNSSSensor	Intern	.../uri/LIMlab/HT/1.4/class/HT.SU.0214	HasPart	HumanTech	1.4 Preview
UltrasonicSensor	Intern	.../uri/LIMlab/HT/1.4/class/HT.SU.0221	HasPart	HumanTech	1.4 Preview
InfraredSensor	Intern	.../uri/LIMlab/HT/1.4/class/HT.SU.0222	HasPart	HumanTech	1.4 Preview
Lidar	Intern	.../uri/LIMlab/HT/1.4/class/HT.SU.0223	HasPart	HumanTech	1.4 Preview
MobileLaserScanning	Intern	.../uri/LIMlab/HT/1.4/class/HT.SU.0312	HasReference	HumanTech	1.4 Preview
TerrestrialPhotogrammetry	Intern	.../uri/LIMlab/HT/1.4/class/HT.SU.0322	HasReference	HumanTech	1.4 Preview
InertialMeasurementUnit	Intern	https://identifier.buildingsmart.org/uri/LIMlab/HT/1.4/class/HT.SU.0	HasPart	HumanTech	1.4 Preview

Figure 7 Example of the relationships that the entity "Robot" has with the other

5. Conclusion and Next Steps

This deliverable demonstrates the feasibility and importance of extending the IFC schema to better represent dynamic and portable entities in construction environments. The example provided by mapping the Robot class to IfcConstructionEquipmentResource, along with relationships to other entities such as scanners and GNSS systems, underscores the need for interoperability between emerging technologies and established BIM workflows.

The methodology applied highlights the significance of enriching the bSDD with meaningful classes, properties, and relationships. While the focus on the Robot class provides a detailed example, the findings are broadly applicable to other temporary and mobile devices commonly used in construction.

To build on this foundation, future steps should include:

- **Standardization:** Collaborating with buildingSMART International and industry stakeholders to refine and formalize these extensions within the global IFC framework.
- **Scalability:** Expanding the schema to include additional classes and relationships, addressing evolving needs in construction technology.

These efforts aim to enhance the efficiency, safety, and adaptability of digital construction workflows, fostering a more connected and innovative industry.

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humantech