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STANDARDIZING CONSTRUCTION SITE EQUIPMENT DATA: AN IFC-COMPATIBLE FRAMEWORK

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Abstract

The evolution of Building Information Modeling (BIM) has emphasized the need for improved construction site design and management. However, existing standards and regulations lack integration of yard data for construction equipment, limiting digital construction site management.

This study addresses this gap by developing a standardized framework for characterizing construction-site parameters within an OpenBIM environment. It also aligns with the Level of Information Need (LOIN) requirements introduced by EN 17412 to improve interoperability and digital site management.

Our methodology involved analyzing European construction taxonomies, BIM authoring tools, and technical data sheets to assess current data availability and define an integration strategy. Therefore, the study proposes a solution based on identifying the most relevant construction-site parameters and developing a standardized approach for their characterization in an OpenBIM environment. It introduces a structured framework to integrate these parameters into the Industry Foundation Classes (IFC) standard.

The results show that while partial feasibility exists, adopting this approach can enhance interoperability and improve data flow within the digital construction ecosystem. This structured framework offers a foundation for more precise and consistent site management, supporting decision-making and advancing OpenBIM applications in construction.

Keywords: Construction Site Equipment, CoSIM, OpenBIM, Interoperability, Industry Foundation Classes (IFC).

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1. Introduction

The evolution of construction site design requires a significant enrichment of information related to construction site machinery and equipment. These elements are fundamental for the effective planning and execution of construction activities, in compliance with health and safety regulations for workers. Despite the growing digitalization and the adoption of methodologies such as Building Information Modeling (BIM), the level of detail concerning technological or productive resources on construction sites often remains insufficient or poorly defined. This shortage represents an obstacle to efficient site management, limiting the possibility of identifying and addressing critical issues in the early project stages and hindering the safe and optimized management of construction operations. Therefore, it is essential to assign proper importance to Construction Site Information Modelling (CoSIM). This discipline is currently underrepresented in the state of the art. Most construction process ontologies (explicit specifications of a shared conceptualization, defining classes, relationships, and functions of a domain of knowledge [1]) focus on individual work activities, considering the construction site as a single entity without further characterizations.

This study addresses this issue by developing a unified system for the classification and management of information regarding construction machinery and equipment. The research proposes a standardized structure, using the Industry Foundation Classes (IFC), to define “property sets” for construction machinery and equipment, integrating essential technical data for site planning within an OpenBIM environment.

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2. Literature Review

Efficient resource management on a construction site requires precise and standardized classification of site elements, including equipment, machinery, and temporary works. This study analysed the main construction site taxonomies used at international and national levels, aiming to identify the most complete and suitable one for managing construction site resources. The literature highlights a lack of studies specifically dedicated to the classification of construction site elements.

From the document analysis, it appears that the Italian Legislative Decree 17/2010 and the European Directive 2006/42/EC mainly focus on safety, functionality, and market compliance of construction machines and equipment. However, these regulations do not provide a complete classification framework for organizing construction site resources. International standardization institutes have developed relevant cataloguing systems. Among these are standards such as UniFormat II [2], UNI EN 474 [3], ISO 6707 [4], ISO 6165 [5], ISO 12006-2 [6], BS 6100-12 [7], DIN 30754 [8], UniClass [9], MasterFormat [10], and OmniClass [11]. Although not all of them specifically focus on construction machinery and equipment, they offer useful classification structures for organizing and managing site resources.

All analyzed taxonomies adopt a hierarchical enumerative structure, ensuring lexical uniqueness and standardization. However, differences emerge in their purposes and resource description methods. BS 6100-12 focuses on resolving lexical ambiguities in contracts [7], while UniClass [9] and OmniClass [11] are oriented toward BIM and digital project management. Conversely, the Lombardy Region Price List, from Italy [12], integrates linguistic standardization with cost analysis. In terms of detail, the Lombardy Region Price List stands out for its five-level subdivision, offering very specific classifications. UniClass presents the highest number of entries (631), while OmniClass and BS 6100-12 are similar (about 350 entries each). However, not all entries in UniClass and OmniClass are strictly related to construction sites, as they also include management and design tools. The comparison between the taxonomies shows that the Lombardy Region Price List is the most suitable tool for detailed and specific classification of construction site elements. Its structure, combined with its integration of cost analysis and properly standardized definitions of various site resources, makes it particularly useful for construction site management.

3. Methodology

To systematically address the problems related to integrating construction site information into OpenBIM processes, the study started with a critical analysis of existing European taxonomies on construction equipment.

It then proceeded by defining the main technical and functional parameters to be included in property sets for site modeling. These parameters were identified by analysing technical datasheets from productive and technological resources available on the market. At the same time, a selection of the main construction site attributes was carried out, aiming to define their usefulness in the context of tender design activities, namely the phase related to the preparation of technical and administrative documents needed to launch a public tender, according to Directive 2014/24/EU [9].

Another methodological axis concerned the integration of information into OpenBIM models using the IFC (Industry Foundation Classes) standard, promoted by buildingSMART. This integration was supported by structured data representation using Express-G, which is useful for describing relationships between parameters and ensuring semantic consistency within the information environment.

3.1. Research goals

The research has several objectives aimed at improving the integration of construction site information about technological and productive resources within the OpenBIM environment. The study aims to analyse and determine the most relevant construction site determinants associated with construction site elements through "property sheets." It also seeks to explore how the identified construction site information can be integrated and structured according to the IFC standard, using EXPRESS-G language. The research intended to structure a unified approach for the characterization of site elements

within information models, emphasizing the need for a general information framework depending on different site phases, and promoting interoperability among the various professionals involved in the construction process [13].

3.2. Definition and critical analysis of a "Property Sheet"

A "Property Sheet" is a document that contains, in addition to the various modeling options typical of the software in use, all the technical information related to a specific object or construction machinery, such as dimensions, operating capacity, safety requirements, and performance needed to carry out a specific task. Its importance lies in clarifying in advance, during the design phase, the technical specifications necessary for the safe and functional use of the equipment according to 92/57/CEE. Property sheets help define the necessary resources, allowing for the optimization of future construction operations.

To assess the informational potential of property sheets, a comparative analysis was conducted between two main BIM authoring software programs: CerTus-HSBIM® and ALLPLAN®. The analysis examined the structuring of technical and geometric information for machinery and construction equipment, focusing on their use during the design phase. The analysis focused on three elements: (i) the internal structure of the property sheets, (ii) the level of informational detail regarding productive and technological resources (e.g., cranes, excavators, scaffolding, fences, site cabins), and (iii) the software's ability to integrate or attach technical documentation. It was observed that although both software solutions offer advanced features for geometric modeling, they have significant limitations in the informational characterization of BIM objects, particularly regarding construction site parameters crucial for site planning. Specifically, CerTus-HSBIM® allows a higher level of customization, including editable sections and the possibility to attach technical datasheets, while ALLPLAN® stands out for its interoperability with the IFC standard and advanced modeling of temporary works, but does not allow direct document integration.

The analysis was supplemented by examining IFC objects from online libraries and manufacturer databases (e.g., BIM&CO, BIMobject, CRAMO, TADANO), to compare the informational richness of these objects with the native ones from the software. The analysed objects showed a greater variety and depth of technical data, although they often included information not relevant to construction site design. This research phase highlighted existing criticalities in the informational representation of construction equipment, laying the foundation for the subsequent methodological proposal aimed at structuring specific property sheets for construction site design, in line with current regulations and operational site needs.

3.3. Proposal for a "Property Sheet"

Based on the information lacking found in the main BIM authoring software, a construction site property sheet was developed to integrate functional and operational performance data of construction equipment into BIM models, considered essential for conscious design aligned with safety, efficiency, and environmental compatibility goals. The proposed sheet is based on the systematic analysis of technical datasheets, over 70 sheets were analysed, from major manufacturers, selecting only parameters considered truly significant for the tender design phase. Each parameter was evaluated in terms of usefulness, frequency of presence, and design impact, distinguishing between geometric data (e.g., dimensions, footprint), operational data (e.g., load capacity, excavation depth), and environmental data (e.g., power supply, emissions, accessibility). The approach involves the inclusion in each sheet a minimum performance specification for each essential parameter. For example, for an excavator, if the design requires an excavation depth of at least five meters, the sheet will indicate "Minimum excavation depth: ≥ 5 m." This enables rational selection of equipment during the tender phase, ensuring compatibility between design needs and available market performance. The construction site property sheet model was structured for numerous categories of machinery and equipment (earthmoving, aerial handling, drilling, lifting, pumping, etc.), following the Lombardy Region Price List structure, identifying key parameters organized into standardized tables. These tables are replicable and scalable tools, useful both during the design phase and for technical validation or compliance verification.

3.4. Validation of construction site parameters through a questionnaire

To verify the adequacy of the selected construction site parameters, a survey was conducted through a questionnaire administered to professionals in the construction sector. The survey focused on the most common and widely used models in the industry, such as excavators, loaders, drilling machines, dumpers, lifts, pumps, and aerial platforms. To validate the construction site parameters, a 70% approval threshold was introduced. The analysis of the responses confirmed the validity of most of the parameters identified in the preliminary work, as shown by the examples in Figure 1. For instance, regarding truck-mounted pumps, the "Theoretical production" parameter received a lower approval percentage, suggesting that this information is more important during the execution phase rather than during the tender design phase. The validation thus confirmed the adequacy of the proposed property sheets, providing a solid basis for their implementation within BIM authoring software using the IFC standard and the EXPRESS-G language.

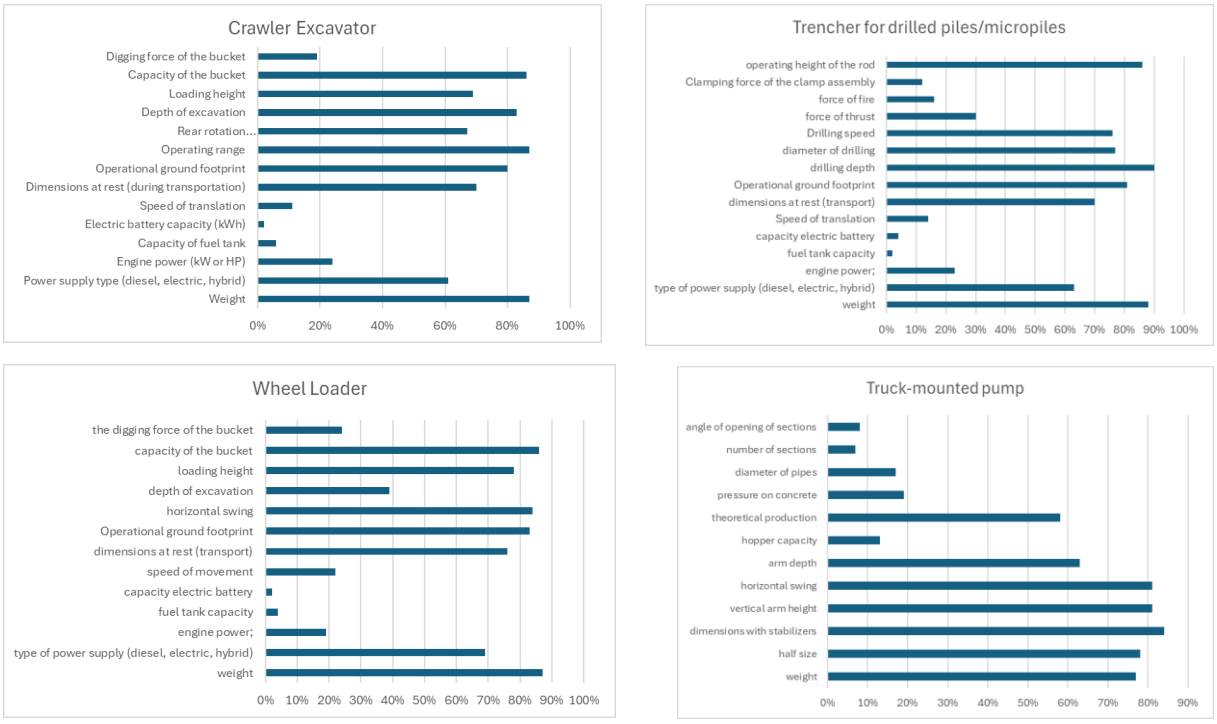

Fig. 1. Validation outcomes of construction site determinants for crawler excavator, trencher for drilled piles, wheel loader, and truck-mounted pump

3.5. Application and validation of the IFC standard to construction site properties

To evaluate the compatibility between the informational needs emerging from the construction site characterization of productive and technological site resources and the IFC v4.3.2.0 standard, a critical analysis of the standard was conducted based on the EXPRESS-G language, as shown in Figure 2. This allowed for an effective schematic representation of the relationships between entities, attributes, and property sets, structuring a generic property sheet.

The analysis showed that the native entity *IfcConstructionEquipmentResource*, although representing the standard reference for the modeling of construction machinery, is inadequate for accommodating specific construction site performance, being limited to parameters related to costs and times. To overcome this limitation, the proposed methodology involved the combined use of generic quantity sets (e.g., *IfcQuantityLength*, *IfcQuantityArea*, *IfcQuantityCount*) and simplified attributes, enabling the association of measurable values to each relevant technical performance, such as operating lengths, volumetric capacities, or geometric limits. This analysis demonstrated the technical feasibility of integrating construction site property sheets into information models, overcoming the limits of the conventional approach through the adoption of a modular, flexible, and software-independent structure.

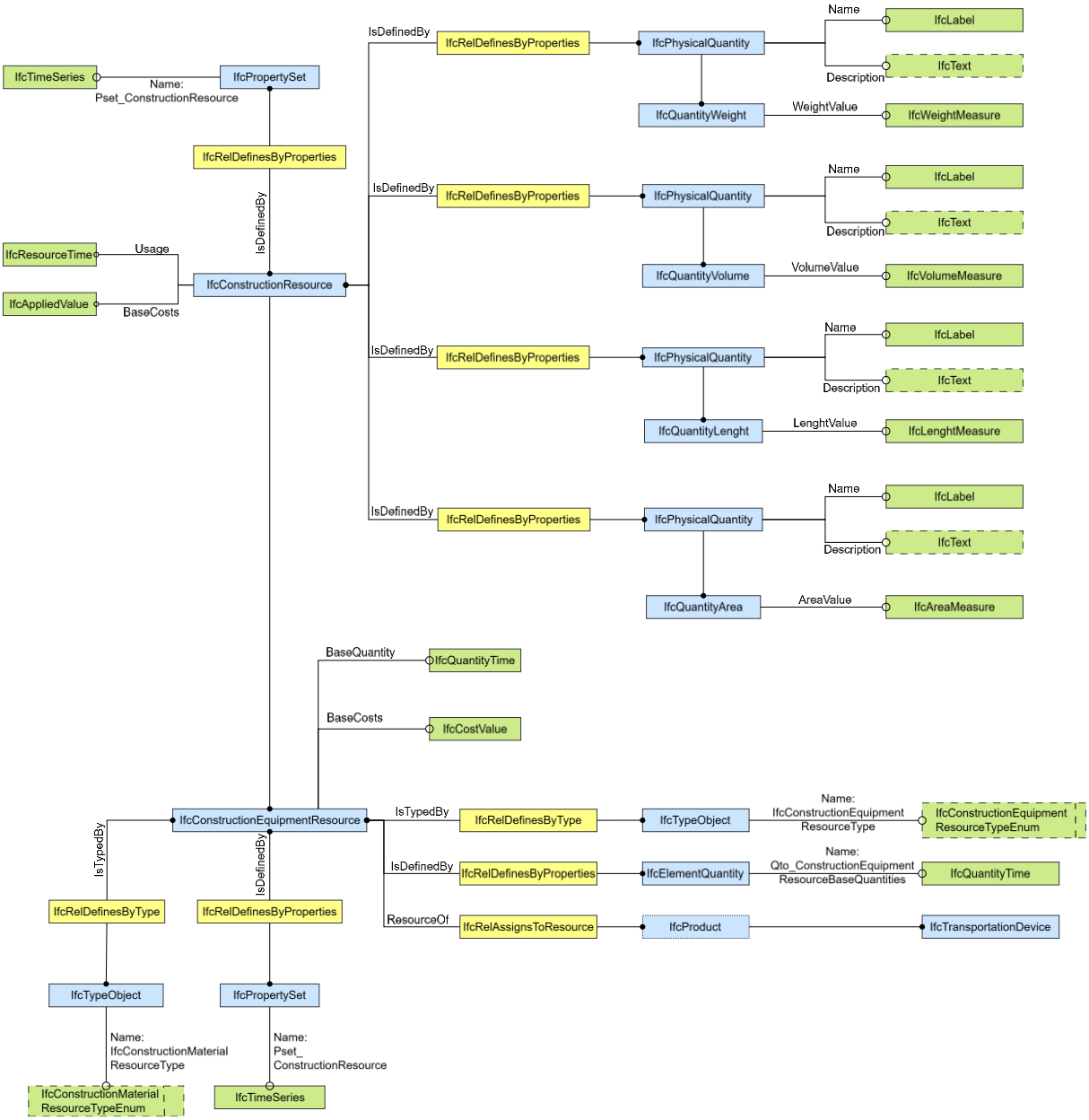

Fig. 2. General map for the implementation of the IFC standard using EXPRESS-G language

4. Discussion and conclusions

The research highlighted the need to move beyond viewing BIM solely as a 3D modeling tool, expanding its conception towards a system for detailed information management. The critical analysis of the informational level currently available in BIM authoring software and online libraries revealed significant shortcomings. To address these deficiencies, property sheets for the most commonly used construction machinery were developed, identifying essential construction site parameters for appropriate design. These sheets allow for the preliminary analysis of potential issues arising from spatial and temporal interferences.

The research focused on implementing these parameters within the IFC 4.3.2.0 standard. It emerged that the management of construction elements in this standard is still inadequate, with a single entity (*IfcConstructionEquipmentResource*) encompassing all equipment and temporary works, leading to lexical ambiguities.

The main future developments of the research concern the practical experimentation of integrating property sheets within BIM authoring software. To concretely test the feasibility of the proposed

framework, it will be necessary to use the *IFCOpenShell* library to query IFC models and translate into machine language what is theoretically expressed through EXPRESS-G. This process would ensure full interoperability and compliance with the IFC standard, guaranteeing that construction site information can be effectively managed across different BIM software. Furthermore, it will be necessary to analyze the degree of interoperability between different software programs, assessing whether the defined construction site parameters remain intact when transferring a model from one software to another, avoiding data loss or compatibility issues. This is crucial, especially for OpenBIM workflows, where the use of the IFC standard must ensure effective information exchange among the various actors in the construction process.

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