information

Systematic Review

Ontologies for the Reconfiguration of Domestic Living Environments: A Systematic Literature Review

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Abstract

The aging population in Europe and other developed regions is accelerating the demand for adaptable domestic environments that support independent living and care at home. In this context, ontologies offer a promising approach to represent and manage knowledge about built environments, smart technologies, and user needs—especially within Ambient Assisted Living (AAL) systems. This paper presents a systematic literature review examining the role of ontologies in the reconfiguration of domestic living spaces, with a focus on their application in design processes and decision support systems. Following the PRISMA methodology, 14 relevant works published between 2000 and 2025 were identified and analyzed. The review explores key aspects such as ontology conceptualization, reuse, engineering methodologies, integration with CAD systems, and validation practices. The results show that research on this topic is fragmented yet growing, with the first contribution dated 2005 and peaks in 2016, 2018, and 2024. Most works (11) were conference papers, with Europe leading the contributions, particularly Italy. Half of the reviewed ontologies were developed "from scratch", while the rest relied on conceptualizations such as BIM. Ontology reuse was inconsistent: only 50% of works reused existing models (e.g., SAREF, SOSA, BOT, ifcOWL), and few adopted Ontology Design Patterns. While 11 works followed ontology engineering methodologies—mostly custom or established methods such as Methontology or NeOn—stakeholder collaboration was reported in less than 36% of cases. Validation practices were weak: only six studies presented use cases or demonstrators. Integration with CAD systems remains at a prototypical stage, primarily through semantic enrichment and SWRL-based reasoning layers. Remaining gaps include poor ontology accessibility (few provide URLs or W3IDs), limited FAIR compliance, and scarce modeling of end-user needs, despite their relevance for AAL solutions. The review highlights opportunities for collaborative, human-centered ontology development aligned with architectural and medical standards to enable scalable, interoperable, and user-driven reconfiguration of domestic environments.

Keywords: Ambient Assisted Living; built environment reconfiguration; ontology for AEC; computer-aided design (CAD) integration; Ontology Engineering in AEC

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1. Introduction

Europe and Western countries are facing a progressive aging of their population: in 2023, the World Health Organization (WHO) observed a worldwide life expectancy of up to 73 years [1]. As a consequence of the general well-being that characterizes European countries, in the USA, and in some countries of the Far East, the percentage of older adults (i.e., persons aged 65 or more) has increased considerably. In particular, Europe is affected by both an increase in older adults and a decrease in birth rates. This condition, also referred to as the "graying of Europe" phenomenon, is expected to be further exacerbated by 2050, when the number of older adults will reach 45% of the total EU-27 population [2].

Older adults may suffer from chronic health issues, temporary conditions of impairment affecting their mobility or perception functions, and cognitive decline—situations that can ultimately culminate in a permanent disability [3]. Moreover, the worldwide aging process forces national healthcare systems to pay a toll: the rise in older adults impacts the national healthcare expenditure, which also needs to cover long-term care [4]. To counter the effect of aging, during the last ten years, the WHO has promoted a holistic and multidimensional approach to active aging, which encompasses physical exercise, mental and social well-being, and ongoing economic, cultural, and social activities for older adults [5,6]. Active aging is expected to make older adults live longer and more independently, and in a better psycho-physical shape.

Moreover, from a technological perspective, the aging of Western countries did not go unnoticed: in the early 2000s, Ambient Assisted Living (AAL) [7,8] emerged as a paradigm to support older adults in living autonomously longer. With the further development of ubiquitous computing, Internet of Things, ambient intelligence, and artificial intelligence, AAL was capable of developing several prototypical solutions, often resulting in residences equipped with various assistive devices—smart homes [9].

However, it is worth observing that while active aging indications are mainly driven by medical professionals, AAL is less structured, and the deployment of its solutions is often contextual. AAL reconfiguration of the living environment requires the physical environment to be redesigned, which forces architects and designers to take into consideration several factors (ranging from occupants' health conditions to the selection and deployment of sensors, the characteristics of the built environment, and the possibility of modifying it). Therefore, AAL reconfiguration of spaces is far from trivial, and architects and designers may not possess all the necessary competencies to fulfill such a task (which is characterized by a clear multidisciplinary vocation) [10–12].

Among the technologies that can be adopted to support architects, engineers, and designers in reconfiguration tasks, domain ontologies play a pivotal role. The management of the built environment and spaces in an AAL context requires the semantic mapping of the environment's components, in particular when building information modeling (i.e., a process involving the creation and management of digital representations of physical and functional characteristics of a building, encompassing occupants' needs, comfort, energy consumption, etc. [13]) is pursued [14,15]. Furthermore, ontologies can support architects and designers with computer-aided design (CAD) modeling of built environments by providing semantic meaning capable of addressing data integration problems [16]. In general, ontologies are known to be capable of supporting the architecture, engineering, and construction (AEC) industry in different ways [17].

Considering the compelling aging situation and the critical situation of national healthcare systems after the COVID-19 pandemic [18], the possibility of making older adults live longer in an autonomous way is a pressing matter. The aim of this review is to provide an answer to the following research questions:

- RQ1: What ontologies are exploited for the reconfiguration of domestic environments?
    - RQ1a: What relevant features are represented by the ontology, and what are the conceptualizations underlying the ontological model of information?
    - RQ1b: What ontology engineering methodologies were adopted to model the ontologies?

  - RQ1c: What are the Ontology Design Patterns (ODPs) adopted to model information in the ontology?
  - RQ1d: Were the inferences generated via the ontology (and by the systems exploiting them) validated with real case tests, or with the support of domain experts?
- RQ2: How are ontologies used to support architects and designers in adding semantic context to their CAD models?

To provide the necessary answers, this paper systematically reviews the scientific literature, contributing to the research on knowledge-based systems for AAL reconfiguration of built environments and ontology-based support tools for professionals.

This paper is organized as follows: Section 2 illustrates the review methodology adopted and the databases searched. Section 3 presents the quantitative results of the review process, while Section 4 discusses them in light of the RQs described above. Section 6 dissects the implications and findings while drafting possible research directions for ontology-based systems aimed at supporting AAL reconfiguration of domestic environments. Finally, Section 7 summarizes the main outcomes of this work.

2. Materials and Methods

This review adopts the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines [19] to systematically search the scientific literature pertaining to the aspects entailed by the RQs. The PRISMA approach is capable of identifying and selecting relevant papers through a step-by-step, reproducible, and transparent process.

This review considers conference proceedings papers, full journal articles, and book chapters published between the years 2000 and 2025, limiting the search to works published in English.

2.1. Databases and Queries

To provide an answer to the RQs, the ISI Web of Science, Scopus, and PubMed databases were searched. All databases provide online access and the possibility to query them using logical operators. Furthermore, all the selected databases allow for limiting the research to specific types of articles (in this case: conference proceedings papers, full journal articles, and book chapters) and time ranges (for this review, from 2000 to 2025).

Three queries were generated to search the scientific literature:

- Q1: `(TITLE-ABS-KEY(ontolog* OR "semantic model" OR "knowledge representation" OR "semantic web")) AND (TITLE-ABS-KEY(reconfiguration OR renovation OR retrofitting OR remodelling OR adaptation OR "home modification" OR "building transformation")) AND (TITLE-ABS-KEY("home" OR "house" OR "housing" OR "domestic" OR "living environment" OR "residential" OR "built environment" OR "household" OR "dwelling"))`
- Q2: `(ontolog* OR "semantic model" OR "knowledge representation" OR "semantic web") AND (reconfiguration OR renovation OR retrofitting OR remodelling OR adaptation OR "home modification" OR "building transformation") AND ("computer aided" OR "CAD")`
- Q3: `(ontolog* OR "semantic model" OR "knowledge representation" OR "semantic web") AND (architect*) AND ("computer aided" OR "CAD")`

Queries Q1 and Q2 intercept those ontology-based solutions aimed at reconfiguring environments by exploiting synonyms, while Q3 focuses on the use of ontologies and derivative knowledge-based products specifically devoted to supporting architectural computer-aided design modeling of an environment.

The queries' results were filtered, focusing on those papers with publication years between >1999 and <2026 (to include those works accepted for publication within 2025 but expected to be published in 2026 issues, thus resulting as "in press"). No preprints were included in the sample, since the review aims to include only works that have undergone a formal peer review, thus focusing on the works' quality. The publication year range was selected considering that in the early 2000s, domain ontologies started to be developed in a variety of fields adopting W3C-endorsed languages (i.e., Resource Description Framework (RDF) [20], and Ontology Web language (OWL) [21]). The database search was conducted in July 2025 and updated in August 2025.

2.2. Article Selection Process and Criteria

Following the PRISMA approach for systematic reviews, the process of identifying and selecting works relevant to the RQs depicted in Section 1 consists of the following steps:

1. *Retrieval* of relevant articles by querying the databases. In this step, considering the three queries, a total of 787 articles was retrieved. Works considered "in press" but already indexed by the databases were included.
2. *Screening* of the retrieved articles. The screening process consisted of removing from the retrieved list those works that were inaccessible (i.e., they could not be retrieved in their complete form for full reading—5 articles) or duplicated works (i.e., those works retrieved from more than one database—38 articles). A total of 43 articles were removed according to this part of the screening process. The screening then proceeded with the analysis of the remaining 744 works' titles and abstracts. This analysis was aimed at assessing whether the papers addressed the domain of ontologies (or ontology-based systems) for the reconfiguration of the built environment. At the end of this step, a total of 689 records were removed due to their titles and abstracts not explicitly addressing the topics reported in the RQs.
3. *Inclusion* of the remaining 554 articles was based on full-text reading of the works. The inclusion of these works was according to the paper meeting at least one of the following criteria pertaining to the physical built environment ($a \vee b$):
    a. The article presents a system exploiting an ontology that is used to represent knowledge of the built environment in a reconfiguration context; this includes guiding the process of deploying smart objects (i.e., sensors, actuators, assistive devices, aids, etc.) in the built environment.
    b. The article presents an ontology capable of interacting with CAD systems in a way that it can potentially also be used to support professionals in the reconfiguration process.

The inclusion criteria and the RQs focused on identifying those papers that exploit ontological representations of the *physical* built environment to support the reconfiguration (or the modification) of a living environment, thus providing help to those professionals involved in such tasks. Therefore, articles focusing exclusively on smart environments' systems management and their orchestration, tackling sensors and actuators' interoperability issues, data collection and organization, the service personalization description of smart environments (without tackling the built environment), or not involving the physical built environment were excluded.

At the end of the inclusion step, 41 papers were removed. Therefore, the number of included works after the process was 14. Figure 1 details the article selection process as a PRISMA flow diagram.

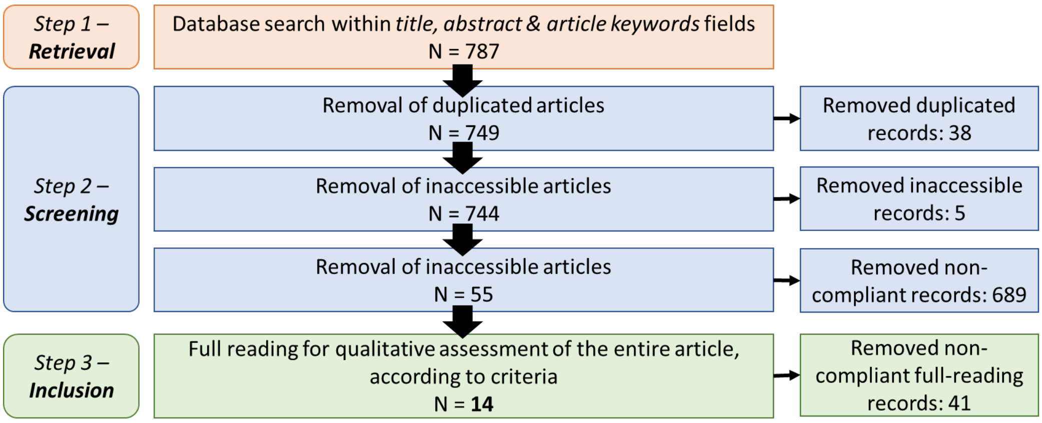

Figure 1. A diagram illustrating the PRISMA process for article retrieval, screening, and inclusion.

3. Results

This section reports the quantitative results of the review, which are discussed in Section 4. The presentation of the bibliometric results focuses on the included articles' types and temporal distribution, while the geographical distribution of authors sheds some light on the areas where these research topics are tackled. The content analysis and its quantitative results are aimed at providing some answers to the RQs depicted in the Introduction by quantitatively investigating and clustering the included works.

3.1. Bibliometric Results

The temporal distribution of the sample of included works is illustrated in Figure 2, which shows that the first contribution pertaining to the RQs is dated 2005. It is interesting to observe that the articles' temporal distribution is discontinuous, with the years 2016, 2018, 2020, 2022, and 2024 marking the highest number of contributions per year (two). Except for the years 2023 and 2024, eligible articles were found every two or three years after 2013—while the gap between the first record (2005) and the second (2009) was 4 years.

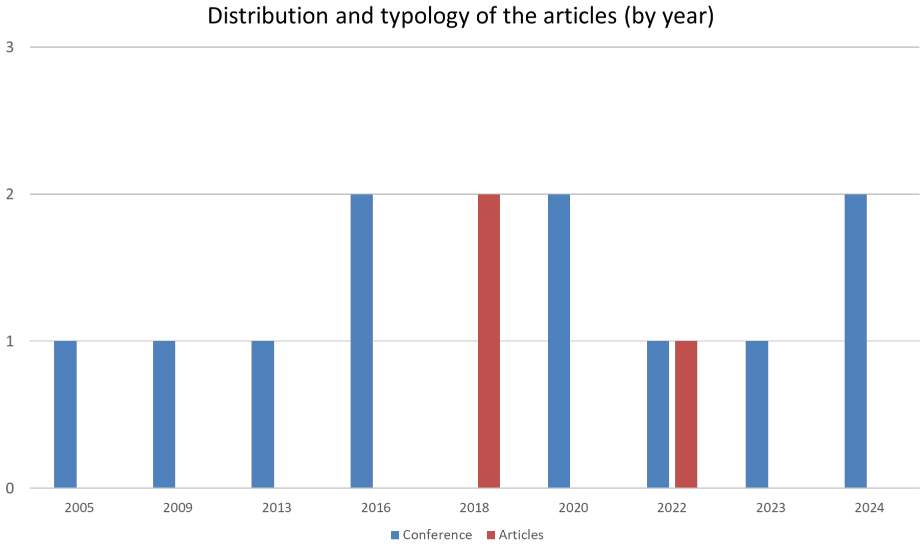

Figure 2. The temporal distribution of articles by year, grouped by their type.

With regard to the types of articles retrieved, the majority of the works belong to the conference proceeding article type (11), with the remaining works belonging to the full-length journal article type (3). In particular, the years 2016, 2020, and 2024 registered the highest number of conference papers (two), while 2018 is the only year with two journal articles.

No book chapters were found that were eligible for this review.

3.2. Geographical Distribution of the Authors

To investigate in which countries the topics of ontologies for the reconfiguration of domestic environments and their adoption to support architects and designers have been addressed, an analysis of the geographical distribution of the articles was performed.

Authors' affiliations at the time of paper publication were considered, and each author was considered only once (the same author, if contributing with two different affiliations pertaining to different countries, was considered twice). Table 1 summarizes the geographical distribution of the authors of the included articles.

The table shows a preponderance of European authors (36), of which Italian authors are the most represented (20); among the other European countries appearing, the Czech Republic, Germany, and Norway count 4 authors each. The only other continent retrieved by this investigation is North America, with Canada leading (six authors), followed by the USA (two).

Table 1. Number of unique authors by continent and country.

Continent	Country	Number of Unique Authors
Europe	Czech Republic	4
	France	1
	Germany	4
	Hungary	1
	Italy	20
	Norway	4
	Switzerland	2
North America	Canada	6
	USA	2

3.3. Content Analysis

The content analysis provides an answer to the RQs, identifying those ontologies that were developed (or adopted) in reconfiguration processes and shedding light on how these models have been used to support stakeholders. This subsection investigates the applicative contexts in which such ontologies were deployed and then delves into the descriptive analysis of the semantic models presented.

3.3.1. Applicative Contexts of the Included Works

To identify the applicative contexts for which the ontologies were developed, this review relies on the IEEE Taxonomy [22]. This taxonomy is a hierarchical classification system used to organize and categorize IEEE publications and resources. It is a subset of the broader IEEE Thesaurus, focusing on the first three levels of each term family. Each included article explicitly states the role played by the ontology in the presented systems; therefore, it is possible to cluster each paper according to the taxonomy's sub-levels.

In Table 2, each work is associated with a maximum of two detailed terms from the IEEE Taxonomy (the first term indicating the family, while the second and third level terms delve into a more specific description of the application context): the first term consists of the main focus of the paper, which can be recognized by reading the full article, while the second term (optional) allows one to specify a secondary applicative context that emerges from the full reading.

It is not surprising that the majority of the works included in this review provide an application in the field of *Computational and artificial intelligence* → *Knowledge engineering* → *Knowledge representation*, since 11 papers present (with more or less details) the TBox of the ontology described (with [23–26] focusing mostly on the ontology description). The second most represented taxonomical term is *Engineering in medicine and biology* → *Medical services* → *Ambient Assisted Living*, which is the main topic of five works [11,12,27–29]; this finding is in line with the RQs and their characteristics. A total of four papers address the problem of using ontologies or semantic data to represent data for CAD in various specific applications, ranging from adding semantically enriched descriptions of ArchiCAD files [30] to supporting the design phase of a building construction or reconfiguration in different ways [11,12,23]. The *Robotics and automation* → *Automation* → *Building automation* term is less investigated among the sample of included works [31,32], together with *Computers and information processing* → *Internet* → *Semantic web* for data interoperablity [33] and *Power engineering and energy* → *Energy* → *Energy consumption* [34].

This classification of the works is completed by a short description of the purpose the ontology represented covers in each work. A good number of studies (four) adopt the ontology as an interoperability enabler, developing frameworks for data exchange among different applications and data schemas [24–26,29,32]. Also, the role of ontologies in adding semantics to CAD models is explored primarily in four articles [11,12,23,30]; adding semantics to CAD models enhances their meaning and interpretability, allowing for better data exchange, reuse, and integration with other systems. Ontologies' reasoning capabilities and data representation can also be exploited in various decision support systems and decision-making tools, as in the case of [31] (in the field of building automation diagnosis) and in [11,12,28], which provide tools to support various professionals (designers, architects, etc.) in the reconfiguration of (parts of) the domestic environments. Ontology development for the representation of a domain of interest is reported in [23,33,34]; these focus on the description and explanation of domain ontologies for various purposes.

3.3.2. Descriptive Analysis of the Ontologies

To answer RQ1's sub-RQs, it is necessary to capture whether the ontologies presented in the included works rely on existing conceptualizations or reuse existing ontologies (and why) in order to correctly identify the features of interest modeled by each ontology (RQ1a). Also, it is important to investigate the ontology engineering (OE) process to assess whether the semantic model is a result of a collaborative process, reuses ODPs, or relies on any shared OE methodology (RQ1b and RQ1c). Finally, the role that ontological reasoning plays is also investigated, with a focus on the ontology's validation in real scenarios or specific use cases (with or without expert evaluation) (RQ1d). Table 3 provides a description of each model from the included works.

Regarding the conceptualization of the built environment domain, half of the included works (seven) opted for developing their ontologies without relying on existing conceptualizations (i.e., "from scratch") [11,23,27–30,32]. The other half of the articles opted for relying on an existing conceptual model, among which building information modeling (BIM) stands out as the most adopted [12,24,25,31,33]. For two works it was not possible to specify the underlying conceptualization: in [26] it is not detailed (although it is mentioned that some conceptual model was followed for the development of the ontology), while for [34] the information is missing since the article presents an extension of DogOnt [35], an existing ontology—therefore, the conceptual model underlying this ontology is the same as DogOnt. Interestingly, BIM is often accompanied by some other standards (as in [24,33]) or data schema [12].

Consistent with the applicative context, the features modeled within each ontology all cover the definition of the built environment, although with different granularities: some articles are more interested in defining domestic areas and what is inside of them (e.g., rooms, such as in [11,27–29,32,34]) while other works are more focused on the physical components of the built environment [12,23,26,30,31]; finally, in line with their aim, a few articles adopt a description of the environment's functionality with regards to data exchange and to solving interoperability issues [24,25,33].

By observing the ontologies described in the articles, it is possible to state whether their development took advantage of any existing semantic model; ontology reuse is one of the best practices of OE processes and, in general, the identification of reusable ontologies is performed in dedicated tasks [36]. Reused ontologies can be either imported within the target model (i.e., reused as they are completely or in some of their parts) to support the description of a portion of a domain, or they can be modeled in the target domain ontology by referencing the reused entities with their URIs (a practice named "soft reuse") [37]. Half of the included works did not reuse any model [23,25–27,29–31], while the reuse of existing ontologies is attested in the other half—with three articles making use of the soft reuse choice [10,12,35], one article importing entire models [28], and three articles not specifying the type of reuse selected [24,32,33]. Focusing solely on those ontologies that fall in the domains of the RQs, the reused models pertain mostly to the area of appliances and sensors: the Smart Appliances Reference (SAREF) ontologies [38], the Sensor, Observation, Sample, and Actuator (SOSA) ontology [39], and the Semantic Sensor Network (SSN) [40] ontology are those with the highest numbers of occurrences (respectively, two, two, and one times). Nevertheless, well-known ontologies in the field of buildings are also reused: the Building Topology Ontology (BOT) [41] and ifcOWL (which provides an ontological representation of the Industry Foundation Classes (IFCs) [42]) are reused twice in three different articles ([24], which uses both ontologies; [32], which adopts BOT; and [11], which refers to ifcOWL). Other useful ontologies in the field of construction and built environment industries pertain to the measurement of quantities; in this case, the QUDT ontologies [43] are reused in two works [24,33].

Another best practice of OE is the adoption of ODPs (i.e., "micro-ontologies" reusable for modeling solutions that address recurring problems in ontology development [44]), which could facilitate the ontologies' alignment and shareability. Among the papers included, only two reused an ODP—which is not designed for the built environment, but rather for the definition of a person's health condition.

In general, ontologies are developed following an ontology engineering methodology (OEM), which may also provide some guidance in authoring the ontology's code (for instance, by suggesting including some ODPs). The vast majority of the selected papers adopted an OEM. Among these works, six [23–25,32–34] opted for a custom methodology, a set of steps and activities that is customized according to the ontology engineers' needs [45], and that is usually sketched before describing the ontology; in [33], the custom OEM is specified in another referenced work. Two works [11,12] refer to an agile OEM (AgiSCOnt [46]), one [28] adopts the NeOn methodology [47], one adopts the Ontology 101 methodology by Noy and McGuinnes [48], and one adopts the Methontology [49]. Aside from the use of an OEM, OE best practices underline that cooperation among different stakeholders (ontology-based system end-users, domain experts, professionals, etc.) when developing the knowledge base is pivotal for its shareability and to acquire an appropriate, shared, and complete representation of a domain of knowledge. However, only a few works among those included explicitly mention a collaborative approach when developing the ontology [11,12,24,26,28].

Table 2. The applicative contexts for the included works, according to the IEEE Thesaurus.

Reference	**Applicative Context**		**Description**
	Term 1	**Term 2**	
Kraft & Schneider [30]	Electronic design automation and methodology → CADCAM	Computational and artificial intelligence → Knowledge engineering → Knowledge representation	Development of an ontology-based extension for ArchiCAD to support designers in conceptual design by adding semantics to spaces and objects.
Kadouche et al. [27]	Engineering in medicine and biology → Medical services → Ambient Assisted Living	Computational and artificial intelligence → Knowledge engineering → Knowledge representation	A semantic framework for the enhancement of indoor environments for persons with disability in an AAL context.
Loffreda et al. [23]	Computational and artificial intelligence → Knowledge engineering → Knowledge representation	Electronic design automation and methodology → CADCAM	An SWRL rule layer applicable to support design processes in CAD and BIM projects.
Dibowski et al. [31]	Robotics and automation → Automation → Building automation	-	An ontology-based framework for fault detection and diagnostics in building automation systems.
Niknam & Karshenas [33]	Computers and information processing → Internet → Semantic web	Computational and artificial intelligence → Knowledge engineering → Knowledge representation	An ontology-based framework for information interoperability among different stakeholders in the architecture, engineering, and construction domains.
Bonino & De Russis [34]	Power engineering and energy → Energy → Energy consumption	Computational and artificial intelligence → Knowledge engineering → Knowledge representation	DogOnt adaptations for the energy consumption and performance assessment in smart environments.
Spoladore & Sacco [28]	Engineering in medicine and biology → Medical services → Ambient Assisted Living	Computational and artificial intelligence → Knowledge engineering → Knowledge representation	An ontology-based decision support system to support designers and architects in reconfiguring domestic environments for people with disabilities.

Table 2. *Cont.*

Reference	Applicative Context		Description
	Term 1	**Term 2**	
Mirarchi et al. [24]	Computational and artificial intelligence → Knowledge engineering → Knowledge representation	-	A semantic framework for data interoperability among different ontologies in the architecture, engineering, construction, and operations domains.
Cao & Hall [25]	Computational and artificial intelligence → Knowledge engineering → Knowledge representation	-	Ontology for the representation of buildings, their structure and composition, and their constraints (customer requirements and regulations).
Amorocho et al. [26]	Computational and artificial intelligence → Knowledge engineering → Knowledge representation	-	An ontology-based decision support system for decision making in the renovation domain.
Ngankam et al. [29]	Engineering in medicine and biology → Medical services → Ambient Assisted Living	Computational and artificial intelligence → Knowledge engineering → Knowledge representation	An ontology for representing the interactions among AAL, IoT, CA, and smart homes (and their components) to describe assistance solutions.
Kaldheim et al. [32]	Robotics and automation → Automation → Building automation	Computational and artificial intelligence → Knowledge engineering → Knowledge representation	A knowledge-based system for building knowledge representation and integration.
Spoladore et al. [11]	Engineering in medicine and biology → Medical services → Ambient Assisted Living	Electronic design automation and methodology → CADCAM	An ontology-based decision support system for the reconfiguration of domestic environments for older adults or people with disabilities.
Spoladore et al. [12]	Engineering in medicine and biology → Medical services → Ambient Assisted Living	Electronic design automation and methodology → CADCAM	An ontology-based decision support system for the reconfiguration of domestic environments for older adults or people with disabilities.

Table 3. The analysis of the domain ontologies from the selected works.

Reference	Concept.	Features Modeled	Reuse		ODPs	Maintenance		Engineering			Ontological Language	Validation
			Reused Ontologies	Type of Reuse		Accessibility	Alignment	OEM Adopted	Collab. Approach	Editor		
Kraft & Schneider [30]	From scratch	Classes of buildings, functional entities of buildings, building and entities' attributes, rules	—	—	—	—	—	Not specified	Not specified	Protégé	OWL DL	Use case
Kadouche et al. [27]	From scratch	Domestic environment (rooms, furniture, bathroom fixtures), reasoning rules	—	—	—	—	—	Not specified	Not specified	Not specified	OWL DL; JENA 2 for rules	Demonstrator
Loffreda et al. [23]	From scratch	Building design classes and properties, rules, Revit shared parameters	—	—	—	—	—	Custom	Not specified	Protégé	OWL DL; SWRL	—
Dibowski et al. [31]	BIM	Characteristics of the building and its equipment (with status and properties), requirements, faults and diagnosis, rules	—	—	—	—	—	Not specified	Not specified	Not specified	OWL DL; SWRL	—
Niknam & Karshenas [33]	BIM, UNIFORMAT II	Selected BIM elements, building elements, project schedule information	QUDT (for quantities)	Not specified	—	—	—	Custom [50]	Not specified	Protégé	OWL DL; SPARQL	Demonstrator
Bonino & De Russis [34]	—	Abstract representation of the indoor environment and buildings (building, storey, flat, etc.); physical structures (ceiling, walls, floors, etc.) and rooms are also modeled; properties for sensor and actuator locations in the space	SSN	Soft	—	A	SAREF, SSN, UCUM, Good Relations; potential alignments with ThinkHome, EEOnt, SEMANCO-HEAD	Custom	Not specified	Not specified	OWL DL	—
Spoladore & Sacco [28]	From scratch	Rooms, appliances, sensors, and actuators to be deployed in the domestic environment	SOSA, FOAF (user), ICF (for health)	Import	Health status [51]	B	—	NeOn	Yes	Protégé	OWL DL; SWRL	Use case
Mirarchi et al. [24]	BIM, ISO 15296	Data structures for achieving semantic interoperability among different construction standards in BIM environments (physical structures, sensors, actuators, etc.)	BOT, ifcOWL, SOSA, SAREF, QUDT, BFO, and others not directly connected to the construction industry	Not specified	—	C	With all reused ontologies (BFO in particular)	Custom	Yes	Not specified	OWL	—

Table 3. *Cont.*

Reference	Concept.	Features Modeled	Reuse		ODPs	Maintenance		Engineering			Ontological Language	Validation
			Reused Ontologies	**Type of Reuse**		**Accessibility**	**Alignment**	**OEM Adopted**	**Collab. Approach**	**Editor**		
Cao & Hall [25]	BIM	Converts BIM schemas into an ontology; it is capable of representing physical structures, environments, and their characteristics (if they exist within the BIM schema)	—	—	—	—	—	Custom	Not specified	Protégé	OWL DL; SWRL for rules	—
Amorocho et al. [26]	Unspecified decision making model in the field of constructions	Building features, characteristics of renovation projects, involved stakeholders	—	—	—	—	—	Ontology 101 [48]	Yes	Protégé	OWL DL; SPARQL	—
Ngankam et al. [29]	From scratch	Environments and their characteristics, including physical structures and furniture	—	—	—	—	DOLCE, DUL, SSN	Methontology [49]	Not specified	Protégé	OWL DL; SPARQL	—
Kaldheim et al. [32]	From scratch	In addition to BOT's building features, the knowledge base accounts for engineering project management concepts	BOT	Not specified	—	D	—	Custom	Not specified	Not specified	OWL DL; SPARQL	—
Spoladore et al. [11]	From scratch	Environments (rooms) and their geometry, physical structures, furniture, appliances, sensors, actuators	ifcOWL, ICF, ICD (health)	Soft	—	—	—	AgiSCOnt [46]	Yes	Protégé	OWL DL; SWRL	Use case
Spoladore et al. [12]	BHoM (model schema to categorize the structural elements), BIM	Environments (rooms) and their geometry, physical structures, furniture, appliances, sensors, actuators	SAREF, FOAF (user), ICF, ICD (health)	Soft	Health status [51]	—	—	AgiSCOnt [46]	Yes	Protégé	OWL DL; SWRL	Use case

Note: Dashes (—) indicate unavailable information. A: https://iot-ontologies.github.io/dogont/ (accessed on 2 August 2025); B: https://www.stiima.cnr.it/wp-content/uploads/D4ALL_ontologies.zip (accessed on 2 August 2025); C: https://w3id.org/digitalconstruction/ (accessed on 2 August 2025); D: https://github.com/Wonkx/KBE (accessed on 2 August 2025).

Regarding the ontology editor adopted, only five works did not share any detail about this field [24,27,31,32,34], while the rest of the articles explicitly mentioned (or showed) Protégé [52] as the selected ontology editor. This can explain why all the articles adopted the Ontology Web Language (OWL) with the Description Logic profile [21] as the ontological language for the representation of knowledge; in this regard, some papers also detail the use of rule languages (Semantic Web Rule Language (SWRL) [53] and JENA 2 [54]) and query languages (SPARQL [55]).

Finally, testing the efficiency and efficacy of an ontology to understand whether it covers all the purposes it was developed to cover is important. In the included articles, only two methods for the validation of the ontological models were retrieved: the *use case* and the *demonstrator*. The first depicts how the ontology should work, exemplifying with some instances the results of the reasoning process, while the second consists of a prototypical application (exploiting the ontology) that relies on the results provided by the ontology. Out of the 14 included works, six presented some validation, with four using the use case [11,12,28,30], and two using a demonstrator [27,33].

4. Discussion

The quantitative results gathered in the Section 3 are discussed here in the light of recent findings in the literature. In particular, the results are discussed from the perspective of recent trends in ontology engineering; moreover, the role of ontologies in the AEC industry (with reference to built environment reconfiguration), the challenges in the adoption of ontologies with CAD systems, and the opportunities ontologies can bring to supporting architects and designers in reconfiguring built environments are addressed. In this process, the included works are analyzed according to recent seminal works, and their content is compared to the most recent and fitting findings.

4.1. Ontologies in AEC for Domestic Environment Reconfiguration: Perspectives on Ontology Engineering

4.1.1. Strategies for Domain Conceptualization and Ontology Reuse

The results from Section 3 indicate that the ontologies represented in the included works are developed either "from scratch" or by relying on an existing conceptualization. The strategy of conducting a domain analysis using an existing conceptual model as guidance is well attested in the OE literature [56], since it enables the possibility of identifying the relevant concepts of a domain by leveraging thesauri, structured vocabularies, taxonomies, or standards (as in the case of the six works relying on an underlying conceptualization). The presence of an underlying conceptual model seems to foster the reuse of existing ontologies, since three works [12,24,33] specified at least one semantic model being imported or soft-reused.

Interestingly, the majority of the underlying conceptualization involves BIM; this could be motivated by the fact that in the early 2000s BIM started to be studied, discussed, and adopted in a more extensive way, and the first attempts to convert BIM schemas into ontologies (which became popular at the same time, thanks to the release of the w3C recommendation for OWL) date from the 2010s [57].

Nevertheless, the "from scratch" approach does not imply that the developed ontologies are simpler; rather, the conceptual models of the works adopting this approach are more focused on specific conceptual items. For instance, in [28,29,32], starting without an underlying conceptual framework enabled ontologists to identify those features relevant for their work—also guided by an OEM. Moreover, two articles also reused existing ontologies in their semantic models. In fact, ontology reuse in the included articles does not seem to be affected by the underlying conceptualization adopted to model the target ontology. In particular, two "from scratch" papers [11,32] explicitly reused ontologies in the building representation domain (respectively, BOT and ifcOWL), while among the papers relying on conceptualizations, only one [24] explicitly reused a couple of building ontologies (BOT and ifcOWL).

In general, the reuse of ontologies is only attested in 50% of the sample of included works—including those papers reusing ontologies not directly pertaining to the AEC domain. This finding is slightly higher than the one reported in [37], which indicates that the reuse rate among ontologies formalizing the same domain is attested around 30%. Nevertheless, it is not possible to draw any firm conclusion about the quality of the reuse: almost half of the papers specifying that they reuse an existing ontology do not share any detail about what the ontology was reused for. This phenomenon aligns with the findings in [58], which highlights that identifying a model to be reused is easier than enacting its reuse during an OE process. Interestingly, a good number of the included works relied on an OEM, either documented or custom (11 articles): in 7 cases [11,12,24,28,32–34] the ontologies generated following these OEMs consider the reuse of existing ontologies; on the contrary, the 3 works not specifying any OEM [27,30,31] do not present any reused ontological model.

It is also worth observing that among those articles that explicitly reused an ontology, only three (from the same authors: [11,12,28]) reused some ontologies for the description of the end-user of an AAL solution (the occupant); this phenomenon is not shared in other papers presenting works pertaining to disability (i.e., [27]) and is discussed also in Section 4.5. Conversely, the reuse of ontologies that can support the quantification of measures in a BIM context is well attested [24,33], as well as the reuse of ontologies pertaining to appliances, sensors, and actuators (particularly, SOSA [24,28] and SAREF [12,24]).

Finally, it is worth observing that none of the included works mentioned any ODP (either cataloged or not) pertinent to the AEC sector. Only those articles that reuse some ontologies may have included patterns coming from the reused models (for example, from SAREF).

4.1.2. Where Is Cooperation in OE?

It is striking to observe a marked lack of cooperation in the development of the ontologies from the selected works. Only five papers described a cooperative approach involving domain experts or other stakeholders during the OE process [11,12,24,26,28]. The cooperative approach is nowadays foreseen in most OEMs [45,58]; however, cooperation in the included articles is attested in less than 36% of cases.

The lack of a collaborative approach might be partially explained by the adoption of rigid underlying conceptualizations. In the case that the ontologists are experts in BIM or any other AEC standard adopted, they might have thought that a straightforward approach (not including the involvement of domain experts or stakeholders) might have accelerated the development and deployment of the ontology.

Nevertheless, the cooperation among ontologists, domain experts, end-users, and various stakeholders placed along the ontology-based system's life-cycle remains central in OE, even in the more recent agile and decentralized OEMs (e.g., UPONLite [59], RapidOWL [60], and other industry-related approaches [61]).

4.1.3. Language and Editor

All the included papers resorted to adopting OWL as their ontological language. The expressiveness of the language is often imposed by the choice of the editor, which, in the case of the selected article, is Protégé for 9 papers out of 14.

In this regard, it is worth observing that Protégé provides the DL profile for OWL, which offers a good trade-off between full-language expressiveness and computational completeness [62]. Moreover, this editor can make use of a DL reasoner (Pellet [63]) capable of processing SWRL rules—which are implemented in five ontologies [11,12,23,25,28]. The query language SPARQL can also be enabled (although with limited functionalities) within the editor, via the plug-in snap-SPARQL [64]. SPARQL is the w3C-endorsed query language for RDF-based graphs; therefore, it can be used to query and modify ontologies, as in [26,29,33].

From an OE perspective, these conservative choices in the selection of ontological, rule, and query languages can foster the shareability of an ontology and their immediate reuse, since these languages are considered as “de facto standards”.

4.1.4. Ontology Accessibility and Maintenance

Less than one-third of the included papers presented a URL or W3id as permanent identifiers for the described ontology. This fact confirms that maintenance is still a neglected aspect of ontology engineering, often resulting in “lost ontologies”, i.e., models that are destined not to be reused because ontologists cannot find them [58].

4.1.5. Validation of the Included Ontologies

As illustrated in Table 3, less than 50% of the ontologies (six papers) described some validation [65] of the resulting outcome. However, the types of validation consist of use cases illustrating how the ontology is expected to work or of demonstrations of ontology-based systems (which cannot be experimentally replicated due to the lack of code).

In other words, the validation for this type of ontological solution in the AEC sector is fairly poor, especially when compared to clinical knowledge-based systems, which score higher percentages on validation and rely on domain experts to evaluate systems’ outcomes [66,67]. This marked difference can be in part explained by the fact that AAL is not yet perceived as a research area in which humans (and their health conditions) are the main focus.

4.2. Reconfiguring Domestic Environments in the AEC Digitalization Process

In a recent review article by Farghaly and colleagues [68], two decades of ontologies developed for the AEC industry are surveyed. The authors conclude that the ontologies can be classified according to their application in the AEC sector, proposing—among others—applications such as *operation and maintenance*, *health and safety*, *monitoring and control*, *sustainability*, and *semantic interoperability*.

All the included articles can be easily ascribed to one (or more) of the applications foreseen by the authors, as depicted in Table 2. However, some interesting considerations can be noted when comparing [68] with this review. Although the scope and the purpose of the two reviews are different, some of Farghaly et al.’s conclusions can also be applied to the findings of this review.

For instance, the topic of semantic interoperability as a means to achieve synergy between two systems is documented in the sample of this review [24,33]. This topic is pivotal in the AEC sector, since there exist several different (ontological and non-ontological) approaches to represent the built environment, what it contains, and what interacts with it. Among the approaches, ifcOWL stands out as the ontological version of the Industry Foundation Classes (IFCs), generated by re-elaborating the EXPRESS schema to an ontological level [42]. However, it is evident from Table 3 that only a few articles reused ifcOWL.

This, as noted by Farghaly and colleagues, may be due to the complexity and size of icfOWL, which hinders its reusability in a real context. As a result, many other ontologies flourished in recent years to represent buildings and their components in a modular way—

usually characterized by smaller sizes. Among them, in this review, it is possible to retrieve BOT. However, there exist several other ontologies that could be reused, but they are not mentioned among the selected papers (e.g., BRICK, Building Product Ontology—BPO, Digital Construction Ontology—DIC, etc.). This phenomenon could be partially explained by the fact that ontologists relied on an existing conceptualization (which, somehow, involved an existing ontology).

In [68], the application named *health and safety* does not take into account the concepts pertaining to AAL; rather, the review considers as part of this application any information pertaining to job hazards and sharing safety data. The present paper, on the contrary, extends the concept of *health* to the end-user of the smart and reconfigured solutions: therefore, the inclusion of ontologies for the description of people (such as Friend Of A Friend—FOAF) or medical vocabularies (such as ICF and ICD) could be perceived as a step forward toward a human-centered approach to AEC in AAL. Nevertheless, Ref. [68] mentions *smart cities* as one of the applications that have interested the AEC sector's digital shift in recent years. In this regard, in the present review, the included article [34] is explicitly addressed to fostering the management and schema mapping among different infrastructures operating in the same building (or groups of buildings). In fact, as noted by Farghaly et al., DogOnt was initially developed for the home automation domain, then expanded to cover energy modeling between devices and the environment from building- towards city- and district-level mappings in smart cities.

4.3. Ontologies as a Vehicle for Data Interoperability Among Smart Objects

As seen in the included works, some works tackled the issue of fostering semantic interoperability between different data schemas, leveraging ontologies' capability of representing information [24,33]. To a lesser extent, other works provided domain ontologies' descriptions that could be potentially reused for the same purpose [25,26,32].

However, the findings underline existing research issues in the field of semantic interoperability among smart objects and built environments. First and foremost, there is no single ontology that fully covers all aspects of smart environments; thus, cross-domain interoperability remains a challenge [69,70]. In fact, the various ontologies present relevant differences in their ontological commitments and underlying standards, thus hindering the seamless integration and wide reuse among AEC stakeholders.

In addition to this semantic fragmentation issue, it is worth noting that balancing logical accuracy, usability, and computational efficiency is difficult, especially as environments scale (e.g., smart objects' configurations may change in different conditions, materials' reaction should be accounted for, etc.) [71,72].

In conclusion, several challenges remain open in the effort of providing seamless semantic interoperability among smart objects.

4.4. Combining Ontologies and CAD Systems

Among the RQs, this review investigates how ontologies are reused to support architects and designers in adding semantic meaning to their CAD models. The rationale behind this question is that CAD models often adopt different data schemas, which makes it strenuous to achieve a consistent semantic mapping across different systems [68,73]. As a consequence, the standard CAD data exchange often lacks in capturing architects' design intent, failing to report essential details such as constraints and construction history, leading to ambiguity and information loss during data transfer between systems [74].

Ontologies, in this regard, can support a collaborative and seamless interoperability among different CAD systems, even between commercial applications [75]. Also, ontology-enriched CAD models can support architects in tasks that may involve the end-users of a smart solution (see, e.g., [76]).

However, the full integration of an ontology-enriched CAD workflow is far from trivial. As pointed out in [68,73], the proliferation of domain-specific ontologies requires manual schema alignment, which is time-consuming and error-prone. Automated ontology-matching tools show promise but still need domain-specific benchmarks and improvements. In fact, one of the challenges consists in integrating various ontologies to support the full building lifecycle—from design to operation—which remains a challenge due to fragmented data sources and evolving requirements [68,77].

Furthermore, traditional ontologies often focus on static geometric data, struggling to represent dynamic behaviors (e.g., motion, temporal changes) and contextual relationships essential for built environments [74,77].

Another relevant challenge in combining ontologies and CAD systems lies in ontologies' extensibility and maintenance: semantic models must be flexible and extensible to accommodate new domains, technologies, and evolving industry standards [68,77]. However, as seen in Section 4.1.4, ontology maintenance seems to be a goal that is difficult to achieve in the AEC context.

Regarding the sample of included papers, these challenges are handled differently. In [30], the an unspecified version of the ArchiCAD software is extended to allow architects and designers to add semantics to building objects and spaces, with the possibility to specify their functionality and constraints. In [23], reasoning capabilities are added over CAD models by implementing an SWRL layer whose reasoning can affect the geometrical aspects of the modeled entities in Revit. Similarly, in [11,12] middleware solutions are devised to bridge Revit representations of a built environment with the semantics of smart devices, aids, and physical modifications to the environment, leveraging BHoM and XML, and reasoning exploiting SWRL rules.

Although promising, these solutions can only scratch the surface of the challenges depicted above, since they consist of prototypical (and, in some cases, incomplete) solutions.

4.5. Selecting Smart Objects and Reconfiguring Spaces: Focus on the Occupants and Their Needs

Selecting smart objects for people with disabilities in built environments presents unique challenges. The main issues are the need for personalization, accessibility, and ongoing support, as well as addressing ethical, usability, and digital divide concerns. These factors are critical to ensure that smart technologies truly enhance independence and quality of life.

Smart objects must be adaptable to diverse disabilities and individual preferences. One-size-fits-all solutions often fail to meet specific needs, making customization essential for effective use [78,79]. Clearly, technologies seem to improve the independence of people with disabilities or older adults facing functional and cognitive limitations, aiming at increasing autonomous living, social participation, and fostering a better quality of life. However, as highlighted in [79], personalization features, solutions' flexibility, and ongoing support to the person with a disability and their close others (e.g., immediate family, caregivers, etc.) remain key challenges.

Despite the ethical issues concerning the deployment and use of smart objects, there are at least two other major challenges to address. The first one is the problem of accessibility, strictly connected to the research topic of universal design. Still, physical and cognitive barriers persist, such as difficulty handling devices or understanding complex interfaces. Universal design principles may help reduce these barriers, but are not always implemented [78,80,81].

Also, it must be considered that the end-users of AAL solutions deploying smart objects are people with disabilities or individuals facing functional and/or cognitive impairments. These end-users often face greater challenges in accessing and using smart devices, which can widen the information divide if not addressed through inclusive strategies [82]. Nam and Park [82] underlined how there exists an accessibility gap in both PC use and smart device adoption for people with disabilities; moreover, this gap is greater in the smart environment.

Within the included works, disability is under-represented. Only four works attempt to model end-users with disabilities or impairments. However, while [27] does not rely on any standard for representing disability (which, in the paper, is mostly represented as "from scratch" classes in SWRL rules), Refs. [11,12,28] reuse international standards for the definition of disabilities (ICF for an individual's functioning and impairment; ICD for indicating the diseases that can affect a person).

In other words, a focus on the end-users of the smart solutions seems to be neglected in the included papers, even in the case of AAL solutions.

5. Limitations of This Study

This review presents some limitations, starting from the limited sample size resulting from the PRISMA selection process (only 14 papers). Combined with the narrow scope of the review (reconfiguration of the domestic environment), the results, insights, and conclusions drawn from this sample might not be fully representative of all ontology-based approaches for environment reconfiguration.

Regarding the composition of the sample, it is important to observe that the majority of works were conference papers: this implies that fewer methodological and technical details were retrieved. Moreover, the inclusion of only English-language work may pose a bias, in that it excludes potentially relevant studies published in other languages.

Additionally, a geographical bias may emerge from the included works. Since the majority of the included works come from Europe and North America, this review's results are difficult to generalize. In one way, the results reflect the current trends in aging populations (which affect mostly Western countries), but may not provide enough generalizable evidence for other countries—which may face aging population issues soon (e.g., China, Japan, South Korea, etc.).

Finally, most papers did not adhere to any of the FAIR principles, making it difficult to provide a quality assessment of the ontologies involved in the included studies.

6. Implications and Research Directions

In this section, the implications involved in the discussed works are presented, divided between theoretical and practical implications. The possible research directions in the field of ontology engineering for AEC and reconfiguration, including AAL systems for persons with special needs, are also presented in this section.

6.1. Theoretical Implications for Ontology Engineering in the AEC Sector

The results and discussion presented in the previous Sections 3 and 4 sketch the status of ontology engineering in the AEC domain when facing the task of reconfiguring a domestic environment.

A significant conclusion emerging from the analysis of the literature is that the best practice of reusing existing ontologies is in good shape. Probably because of the reliance on BIM and other AEC standards, the ontologies from the included works opted for reusing existing models; contrary to the findings of previous studies (e.g., [37]), the AEC sector manages to catalyze researchers' attention towards those OE activities pertaining to the identification of reusable resources. Nevertheless, more details about how ontologies are reused should be shared, although this phenomenon may find a partial explanation in the well-known issues related to ontology reuse in practice [58,83].

It is essential to underline that cooperation in OE has a pivotal role; however, in the included papers, this is a sore topic. The active involvement of domain experts and stakeholders, either at the beginning of the OE process (domain analysis) and at the end (validation of the developed model), is fundamental in any recent major OEM [45,58,61] and cannot be neglected. Ontologies developed without a shared vision from different stakeholders often result in non-reusable semantic models [84–86] and cannot evolve towards meeting stakeholders' necessities.

On the same note, having the ontologies stored on repositories or universally identified with W3IDs would improve maintenance activities, also fostering discussion and possible reuse of the ontologies [87]. Ontology unavailability affects recent and "older" ontologies, with many models dating from 2016 (or even more recently) not retrievable. Thus, it is fundamental to "keep the ontologies alive", also according to the FAIR (findable, accessible, interoperable, and reusable) principles for ontologies and metadata, which can provide solid guidance in this regard [88].

This result could be achieved more easily by relying on solid (and validated) OEMs, which can support ontologists also in the AEC domain, and foster a collaborative approach during the whole OE process.

6.2. Practical Implications for Ontology Engineering in the AEC Sector

As noted in the previous sections, ontologies' accessibility is a major issue. Moreover, the lack of cooperation with stakeholders and domain experts makes it harder to develop reusable and shareable models.

Once again, from a practical perspective, it is essential to note that ontologists should make an effort to follow the FAIR principles, since they can make ontological models universally accessible, interoperable, and thus reusable. Several guidelines and actionable insights were provided in the past five years to make FAIR ontologies a reality [87]. Therefore, new ontologies should be focused on both an inclusive collaborative approach (involving domain experts, stakeholders, dissemination, and validations) and the adoption of FAIR principles.

The combination of a collaborative approach (often fostered by OEMs) with FAIR principles should enable the development of accessible ontologies reusing existing models (or excerpts of existing vocabularies), which can be more easily shared. In this way, the path toward an ecosystem of AEC ontologies could be achieved in a matters of years.

6.3. Conceptualizing for the Reconfiguration of Domestic Environment: The Role of the End-Users

When developing knowledge-based solutions devoted to reshaping or reconfiguring a domestic environment for persons with special needs, the ontologies should account for *what needs* the systems should address. Therefore, the representation of the users and their needs should not be overlooked.

This is particularly valid for those AAL solutions that revolve around the user, bearing in mind that AAL is at the intersection between AEC, healthcare, and home automation.

Considering what emerged in the previous sections, it is clear that the difficulties in focusing on the users and their needs emerge from the lack of cooperation between ontologies and domain experts (and stakeholders, such as representatives of the end-users) and the lack of maintenance in the developed ontologies (i.e., the ontologies are not updated).

Therefore, a collaborative approach should be pursued in the OE process for AEC and AAL. In fact, a multi-stakeholder and FAIR-compliant approach could support the following:

- The accurate identification of conceptualizations and existing ontologies to be reused;
- The representation of *all the actors* (i.e., built environment, devices, end-users) actually involved in the system;
- A careful schedule for ontology maintenance, which includes making the data permanently and widely accessible;
- Fostering interoperability and alignment with existing (and reused) ontological models.

Thus, ontologies in AAL should be considered far from a static representation of a piece of knowledge; rather, they should be considered as a dynamic and evolving artifact, capable of changing and updating to meet end-users' needs—which may vary over the time.

7. Conclusions

This systematic literature review has provided a comprehensive overview of how ontologies have been employed to support the reconfiguration of domestic living environments, with particular attention to Ambient Assisted Living (AAL) applications and architectural design contexts. The analysis of 14 selected works has revealed a steadily growing interest in this domain, albeit with a fragmented and uneven temporal distribution.

Regarding RQ1, ontologies identified in the literature primarily represent built environment features such as rooms, structural components, and smart devices, often extending to include environmental attributes and, in a few cases, user-related aspects. About half of the ontologies were developed "from scratch", while the others leveraged conceptualizations such as BIM schemas. Most works followed some ontology engineering methodology, but the use of Ontology Design Patterns was almost absent, and collaborative development was explicitly mentioned in less than 36% of cases. Validation was limited, with only six works providing use cases or demonstrators.

Concerning RQ2, the review found that integration between ontologies and CAD systems remains at an early, experimental stage. Only four studies proposed approaches to add semantic layers to CAD models or link them to reasoning capabilities (e.g., through SWRL), highlighting potential for enriched design workflows but also underlining current limitations in scalability and automation.

In general, ontologies have proven valuable for supporting semantic interoperability, enhancing CAD-based design processes, and formalizing knowledge about both the built environment and its occupants. However, several critical gaps remain. Reuse of existing ontologies, while present in half of the sample, remains inconsistently applied, with limited documentation on reuse strategies and alignment practices. Moreover, the lack of ontology accessibility and persistent identifiers hampers the sustainability and reuse potential of these models.

A significant limitation is the limited involvement of domain experts, end-users, and stakeholders in the ontology engineering process. Despite the multidisciplinary nature of reconfiguring domestic environments—especially when aimed at older adults or individuals with disabilities—collaborative development approaches were explicitly adopted in only a minority of the studies. Similarly, ontology validation practices were inconsistent, with few papers demonstrating use cases or prototype systems to assess reasoning or applicability in real-world scenarios. These shortcomings suggest a need for stronger adherence to ontology engineering best practices, including cooperative development, transparency in reuse, and FAIR principles to ensure ontologies are findable, accessible, interoperable, and reusable.

Future research should focus on developing human-centered ontologies that accurately capture the needs and constraints of vulnerable populations, particularly in AAL contexts. Greater emphasis should be placed on integrating medical and functional standards such as ICF and ICD, while ensuring alignment with architectural and engineering schemas. Moreover, the coupling of ontologies with CAD systems remains in an early stage, with only a few attempts to enrich architectural models with semantic annotations. Addressing these issues through collaborative, open, and sustainable development methodologies will be essential for advancing intelligent, inclusive, and adaptable living environments capable of supporting the challenges posed by population aging and increasing care needs.

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