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Towards Development of Ontologies of International Property Measurement Standards

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Abstract

The property measurement standards are used to specify different area and volume types in buildings. This paper focuses on reviewing regional and international property measurement standards. Firstly the purposes, principles, terms and definitions of building floor area and volume types of the measurement standards were examined. Later, the relationships between terms and definitions of the measurement standards were identified. Finally, a set of draft ontologies were created for the measurement standards in order to represent terms, term definitions, and the relations between the terms. Terms of the developed ontologies were then mapped to support semantic harmonization of measurement standards.

Keywords: Property measurement standard, Building floor area, Ontology, Property measurement ontologies

1 Introduction

The area and volumes of the land and buildings (and building parts) are used in many application areas such as taxation, valuation, land use planning, building cost planning. The area and volumetric values may be obtained from different sources, such as land registers, cadaster, building and dwelling registers and architectural projects. But, these sources do not provide an explicit information on the standards and methods used to determine them.

Measurement codes and standards focus on measurement and computation methods of area and volume values of land and/or buildings. Many European countries have national codes for measurement of floor area of buildings, e.g. DIN 277:2005 in Germany, ATASA in Spain, and RICS Code of Measuring Practice in United Kingdom. A study conducted by the European Committee of Construction Economists (CEEC) shows that national measurement codes more or less use similar basis for measuring floor areas, but semantic differences between various types of areas specified in national codes often found highly misleading [1, 2]. For instance measuring a specific floor area in one building by using different national codes result in variations up to 30 % [3]. According to International Property Measurement Standards (IPMS), current measurement inconsistencies can create 24% difference in valuations between markets [4, 5]. A number of international standards has been developed for harmonizing measurement practices, such as:

1. International Organization for Standardization (ISO), 9836:2011 Performance Standards in Building – Definition and calculation of area and space indicators;
2. The European Committee for Standardization (CEN), EN 15221-6 - Area and Space Measurement in Facility Management, 2012
3. International Property Measurement Standards Coalition (IPMSC), IPMS for Office Buildings, 2014 and IPMS for Residential Buildings, 2016
4. Royal Institution of Chartered Surveyors (RICS), Code of Measuring Practice, 2007; Property Measurement, 2015.

The objective of these international standards is to provide rules and definitions for measurement of area and volume values, and harmonize national practices. In fact, even they use different terms for the same area and volume types. Besides, content of the standards are different. For example, all standards include rules and definitions for measurement of building floor areas. ISO 9836:2011 and RICS Code of Measuring Practice have definitions about building volumes, while CEN and RICS have a few definitions for the measurement of land.

The literature in the field reveals that, conceptual frameworks of the measurement standards have not been compared yet. Moreover, differences and commonalities of building floor area types defined in above-mentioned standards still have not been exactly identified. This study focuses on developing a framework which may help in the harmonization of area and volume types of land and building specified by different international measurement standards and codes, as it extracts and reorganizes information obtained from the measurement standards, and specifies semantic relationships between these standards. The remaining part of this paper is organized as follows: The next section describes methodology applied. Section 3 briefly examines the property measurement standards and interrelations between them. Section 4 represents draft measurement ontologies which were created according to information represented in the previous sections. The last section concludes present paper with proposals for the further research.

2 Methodology

There are several different property measurement standards, developed and used at national and international levels, due to the time limitations of the study, here we focus on four standards that are more commonly used, and of which the documentation about them is more reachable. In the first stage, selected four measurement standards were examined according their (1) purpose, content and usage, (2) terms, definitions of terms, relations between terms and interrelations between the measurement standards, and (3) rules, principles, restrictions in measurement practices. The information obtained from this stage was then used for creating measurement ontologies in the following stage.

In the second stage, ontologies were created based on examined measurement standards. These ontologies were prepared with Protégé 5.0 software (a well-known ontology development tool), and available online at http://cadastralvocabulary.org/propertymeasurementontologies/. The building floor area types of the standards are illustrated with a Graph Visualization Software (Graphviz). The property measurement standards and their interrelations are examined in the next chapter.

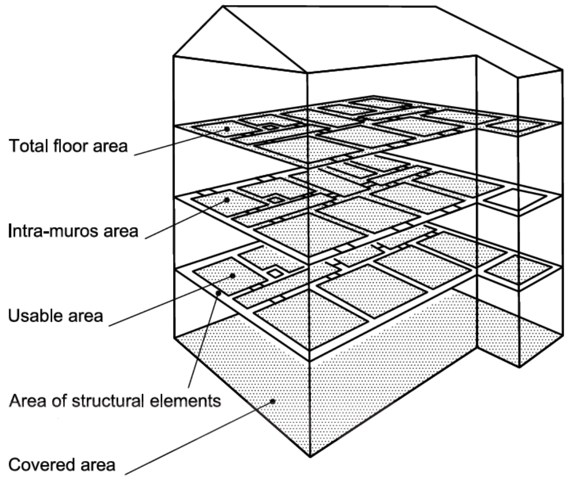
3 Property Measurement Standards

Property measurement standards have similar purposes, such as creating a consistent basis, assisting benchmarking and making interpretations easier building floor area measurements. These standards generally consist of terms and definitions for types of building floor area, relations between area types, and certain rules for measurement of building floor areas. Only the IPMSC standards classify building according to their usage such as office, residential, industrial and retail; while others have general rules which can be applied to all types of buildings. The next subsections examine property measurement standards and their interrelations.

3.1 ISO 9836:2011 Performance Standards in Building – Definition and calculation of area and space indicators

ISO 9836:2011 specify the calculation of area and volume values of buildings [6]. The standard can be applied all kinds of buildings such as office, residential, industrial [6]. It defines 25 different area types. Figure 1 shows main floor area types defined in this standard. ISO 9836:2011 defines 10 terms concerning building volumes and 16 height types (e.g. storey height, building height) used for computation of building volumes.

Figure 1: ISO 9836:2011 principal building floor areas



Source: ISO 9836:2011, p.4

The 'Total Floor Area' is the sum of 'Net Floor Area' and 'Floor Area of Structural Elements' or 'Intra-muros Area' and 'Floor Area of External Walls'. It can be defined as total gross floor area including internal and external walls. All the selected measurement codes and standards contain similar term but their definitions have small differences. For example, 'Gross External Area' in RICS [6] is identical with 'Total Floor Area'. On the other hand 'Gross Floor Area' in CEN 15221-6 has slightly different from that since it excludes voids above technical areas [6]. 'Intra-muros Area' is the gross floor area minus the floor area taken up by the external walls, namely floor area of the building envelope (ISO 9836:2011, p.5). If the 'Intra-muros Area' is enclosed and covered on all sides, it is the same area with 'Gross Internal Area' in RICS code [6]. 'Internal Floor Area' in CEN 15221-6 is different from 'Intra-muros Area' and the difference is the exclusion of voids above technical areas.

'Net Floor Area' is the sum of 'Usable Area', 'Service Area' and 'Circulation Area'. On the other hand, the sum of 'Effective Building Loss Area', 'Effective Floor Area for Occupants' and 'Service Area' is also equal to 'Net Floor Area'. The 'Net Internal Area' of RICS is different from 'Net Floor Area' since it excludes 'Services Area' and 'Circulation Area' defined in ISO 9836 and common areas, toilets, cleaners rooms and areas with a headroom of less than 1.5 m defined by RICS [6].

3.2 CEN EN 15221-6 - Area and Space Measurement in Facility Management

CEN 15221 series of standards are related to facility management, and CEN 15221-6 provides terms, definitions and principles about measurement of floor areas and volumes in building [3]. Although terms, definitions and principles of this standard is related to facility management, it can be employed in entire construction industry.

CEN 15221-6 defines 9 different distance types (e.g. length, width and height), 34 different building area types and only 2 volume types (gross and net volume).

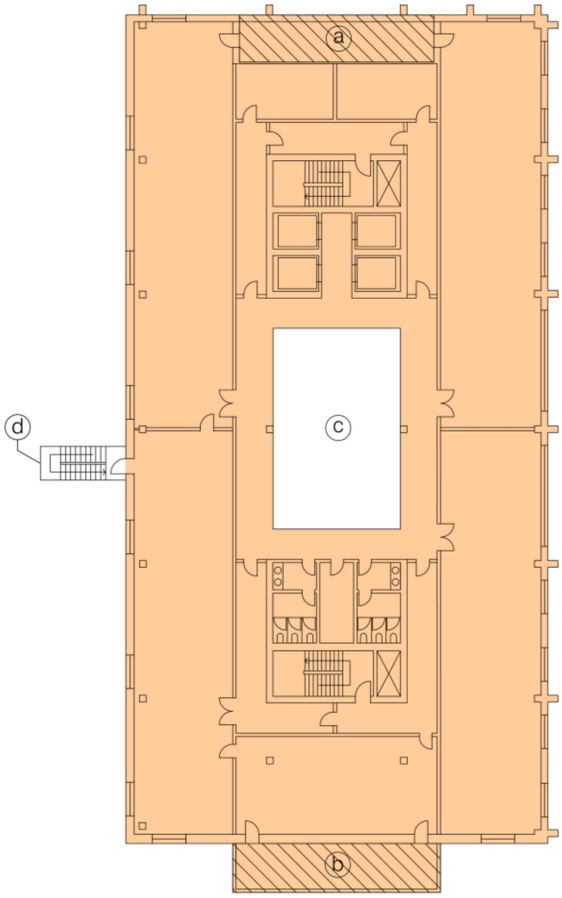
'Level Area' is equal to sum of the 'Gross Floor Area' and 'Non-functional Level Area' [3]. It is similar to 'Gross External Area' defined by RICS, but different from 'IPMS 1'. While the 'Level Area' includes voids and atriums, 'IPMS 1' does not include the upper level voids of atriums. According to CEN 15221-6, 'Gross Floor Area' is calculated 'Level Area' excluding 'Non-Functional Level Area'. 'Internal Floor Area' is the sum of 'Net Floor Area' and 'Interior Construction Area', but it is different from the 'Gross Internal Area' defined by RICS. While 'Internal Floor Area' does not include 'Non-functional Level Area', 'Gross Internal Area' includes service voids and areas with a height below 1.5 meter.

3.3 IPMS Office Buildings and Residential Buildings

The IPMSC comprises the 84 organizations including RICS, International Federation of Surveyors (FIG) and International Association of Assessing Officers (IAAO), among others. It aims 'to bring about the harmonisation of national property measurement standards through the creation and adoption of agreed international standards for the measurement of Buildings' [8]. Until now, IPMSC published two standards: IPMS Office Buildings (2014) and IPMS Residential Buildings (2016). IPMS Industrial Buildings and Retail Buildings will (probably) be published in 2017. The members of IPMSC have started to put the standards into practice. For example, RICS made a statement to its members that IPMS Office Buildings is mandatory for RICS members from 1 January 2016 and RICS Code of Measuring Practice (6th edition, 2007) is no longer applicable unless the client instructs otherwise [10].

30 terms concerning to building floor area are defined in IPMS Office Buildings. There is no definition of height or volume in this code. The code specify 3 reference building floor area terms. The first area defined in the code is 'IPMS 1' which includes the areas of balconies, covered galleries, accessible rooftop terraces. The 'IPMS 1' excludes the areas of open light wells, upper level voids, open external stairways, patios and decks at ground level and external car parking. Figure 2 shows a floor plan illustrating the areas defined in the 'IPMS 1'.

Figure 2: IPMS 1 (a- Covered gallery, b- Balcony, c- Open light well/upper level void of atrium, d- Open external stairway)

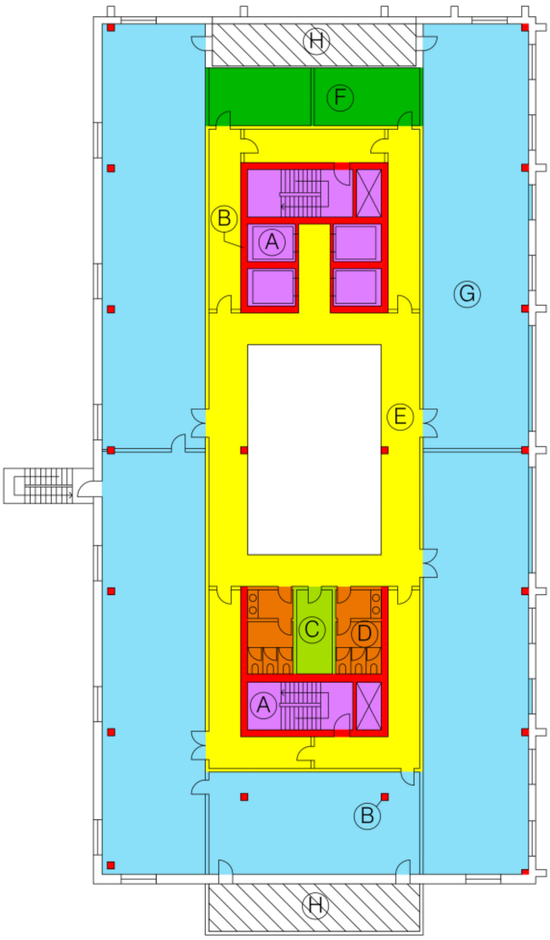


Source: IPMS – Office Buildings, 2014, p.11

The measurement of 'IPMS 2 – Office' area starts from the internal dominant face of each floor and includes internal walls, columns, enclosed walkways, balconies, covered galleries [7]. The internal dominant face is defined as 'the inside finished surface comprising 50% or more of the surface area for each Vertical Section forming an internal perimeter'. The area of 'IPMS 2 – Office' can be used in applications such as facility management, valuation and transactions [7]. Figure 3 shows the components of the 'IPMS 2 – Office'. The 'Gross Internal Area' of RICS is slightly different from 'IPMS 2 – Office' area. 'Gross Internal Area' of RICS includes internal balconies, roof terraces and the area difference from internal dominant face but 'IPMS 2 – Office' is not [10]. 'Internal Floor Area' of CEN is also slightly different with the area of 'IPMS 2 – Office'.

The measurement of the areas in 'IPMS 2 – Office' and 'IPMS 3 – Office' is taken from internal dominant face for external walls or otherwise horizontally at wall-floor junctions, ignoring skirting boards, heating and cooling units, and pipework [7]. All internal walls and columns are included within 'IPMS 3 – Office' that is calculated occupier-by-occupier or floor-by-floor basis and excluding standard facilities and shared circulation areas [7].

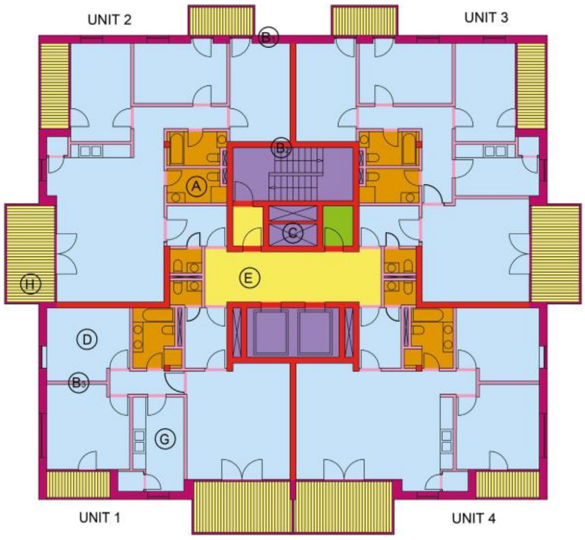
Figure 3: IPMS 2 - Office (A-Vertical penetrations, B-Structural elements, C- Technical services, D- Hygiene areas, E- Circulation areas, F- Amenities, G- Workspace, and H-Other areas)



Source: IPMS – Office Buildings, 2014, p.17

The other standard published by IPMSC is about Residential Buildings. 42 area types and a few height types (e.g. clearance and full heights) are defined in this standard. The measurement principles are almost same with the IPMS Office Buildings. The area ‘IPMS 1 (External)’ is measured outer perimeter of the external walls and generally used for planning purposes [8]. ‘IPMS 1 (External)’ includes columns, balconies, verandas, internal catwalks, sheltered areas and internal permanent mezzanines [8]. While ‘IPMS 1 (External)’ is equal to sum of all component areas defined in this standard (see Figure 4), The ‘IPMS 2 - Residential (Internal)’ is equal to the aggregate of the component areas minus external wall [8]. The measurement of ‘IPMS 2 - Residential (Internal)’ is to be taken from internal dominant face of the each floor [8]. ‘IPMS 2 - Residential (Internal)’ is different from ‘Internal Floor Area’ of CEN and the differences are internal columns, partitions and non-structural wall. There are three variations of ‘IPMS 3. The area of ‘IPMS 3A – Residential’ includes the areas of attics, basements, balconies and verandas in exclusive use, enclosed garages and limited use areas but patios, unenclosed parking areas, staircase openings, vertical penetrations and voids greater than 0.25 m² are not included [8]. The measurement of ‘IPMS 3B – Residential’ is to be taken from internal dominant face and finished surface of internal perimeter walls. ‘IPMS 3B – Residential’ includes the floor area occupied by internal walls and columns. Lastly, ‘IPMS 3C – Residential’ excludes the floor area occupied by full-height, permanent, internal walls and columns [8].

Figure 4: IPMS 1 – Residential Apartments Component Areas (A-Vertical penetrations, B1- External wall, B2-Internal structural elements, B3-Internal non-structural elements, C-Technical services, D- Hygiene areas, E- Circulation areas, F-Amenities, G- Living space, and H-Other areas)



Source: IPMS – Residential Buildings, 2016, p.19

3.4 RICS Code of Measuring Practice

RICS is a professional body that accredits professionals within the land, property and construction sectors worldwide. The practice areas of RICS are geomatics, environment, planning, construction and valuation. RICS Code of Measuring Practice defines building floor areas for using in commercial processes, valuation, management, conveyancing, planning, taxation, sale, letting and acquisition [9].

The code defines three reference area types: ‘Gross External Area’, ‘Gross Internal Area’ and ‘Net Internal Area’. Besides the reference definitions, the code also provides eight more area definitions, e.g. for shops, residential and leisure properties [9]. Also several height types are defined including ceiling, eaves (external, internal), maximum internal, clear internal and raised floor heights. The only volume type is the ‘Cubic Content’ which is defined as the product of the ‘Gross Internal Area’ and the appropriate internal height [9].

‘Gross External Area’ is defined in RICS code as ‘the area of a building measured externally at each floor level’ [9]. Open balconies, terraces, parking areas, canopies and voids are excluded for this area type [9]. ‘Gross Internal Area’ according to RICS is measured from the internal face of the walls for each floor and excluded the wall thicknesses and external projections [9]. ‘Net Internal Area’ is measured from the internal dominant face of the walls and it specifies the usable area within the each floor of building [9]. ‘Net Internal Area’ excludes the areas with a headroom of less than 1.5m, toilets, bathrooms and heating and cooling systems that penetrate 0,25 meter or more into the usable area [9].

4 Property Measurement Ontologies

An ontology may provide sharing a common understanding in specific domains, reusing domain information and expressing definitions, relations and interrelations of domains, explicitly [11]. There are different types of ontologies such as Resource Description Framework Schema (RDFS) and Web Ontology Language (OWL). In this study, OWL is chosen due to richness of language and powerful mechanisms for defining mappings between terms of different vocabularies [12].

An OWL ontology includes classes, properties, instances of classes and relations between instances. A class in OWL refers to classification of something. Every individual is the member of owl:Thing class in the OWL and each defined class is subclass of owl:Thing [13]. The characteristic of the classes are determined with properties and constraints. There are two different types of properties in OWL. If a property relates individuals to individuals, it is an object property; if it relates individuals to literals, it is a datatype property. In addition to this, there are value and cardinality constraints in OWL. While the value constraints are used for restricting the range of the properties when they applied to the class description, cardinality constraints are used to limit the number of values a property can take [14]. owl:allValuesFrom and owl:someValuesFrom are types of value constraints. The ontology languages provide extra properties that do not contribute to the logical knowledge but give additional information for enriching the ontology with annotations and document information such as owl:versionInfo, owl:sameAs and rdfs:seeAlso [15]. The owl:sameAs property provides links between two URI references that actuaaly refer to the same thing [16]. The rdfs:seeAlso property is used for providing additional information about the resource [17].

In this study, measurement ontologies are created for each examined standards with the information obtained from the previous section. The open source tool Protégé ontology, which uses Java OWL API 4.1.3 and supports the OWL 2, is utilized for the development of property measurement ontologies.

Firstly, the ontology classes are specified for each standard. The property objects that are subjects to measurement can be classified as ‘Land’, ‘Building’ and ‘Floor’. These objects are represented as class with owl:Class definition in the Protégé. After that, ‘hasFloor’ and ‘hasBuilding’ objects properties are identified for each of the property measurement ontologies. In Protégé, expression of ‘Building hasFloor only Floor’ defined to the ‘Building’ class. It means that all the instances of ‘Building’ class that have ‘hasFloor’ property, only can have the instances of class ‘Floor’. In a similar manner, ‘Land hasBuilding only Building’ expression is defined the for the ‘Land’ classes. Table 1 shows that the OWL Turtle syntax of the expression.

Table 1 Fragment of ISO 9836 Ontology - all values from value constraint

```
   http://cadastralvocabulary.org/propertymeasurementontologies/I
SO9836/Building
   <http://cadastralvocabulary.org/propertymeasurementontologies
/ISO9836/Building> a owl:Class ;
              rdfs:subClassOf
<http://cadastralvocabulary.org/propertymeasurementontologies/I
SO9836/ISO9836:2011> , _:genid1 .
  _:genid1 a owl:Restriction ;
              owl:onProperty
<http://cadastralvocabulary.org/propertymeasurementontologies/I
SO9836/hasFloor> ;
              owl:allValuesFrom
        <http://cadastralvocabulary.org/propertymeasurementontol
        ogies/ISO9836/Floor> .
```

Next, datatype properties and their ranges were specified in the exercise. The property measurement standards have a number of terms about distances, areas and volumes. These terms were specified as datatype property and their ranges are specified with a numerical datatype such as decimal and integer. Since the measurement standards use floor-based measurement, most of terms were related to building floor. Therefore, there are many expressions in the‘Floor’ class. For example, ‘Floor has TotalFloorArea exactly 1 xsd:decimal’ expression means that a floor has exactly one total floor area with a decimal value.

Then, the semantic links between the developed ontologies are specified with the owl:sameAs and rdfs:seeAlso annotation properties. If a term refers to the same fact with another term, owl:sameAs is used; if a term is slightly different with another term, rdfs:seeAlso is used. For example, the term ‘Total Floor Area’ of ISO 9836 is the same with the ‘Gross External Area’ of RICS, however, the ‘Gross Floor Area’ of CEN 15221-6 is slightly different from these areas. Therefore definitions of ‘Total Floor Area’ are included owl:sameAs with ‘Gross External Area’ and rdfs:seeAlso with ‘Gross Floor Area’ properties.

The draft property measurement ontologies in OWL turtle format and their HTML representations are now available online for inspection and feedback at http://cadastralvocabulary.org/propertymeasurementontologies/.

5 Conclusion

The area and volume measurement of buildings may have many consequences in legal and financial world. The international and regional standard setting-bodies create high level measurement standards for measuring the properties in consistent basis and providing transparency. However, the high level measurement standards use different terms, definitions and principles. This study examined these standards, and revealed commonalities and differences between standards through developed measurement ontologies.

The results of the study demonstrates that the measurement standards generally concentrate on building floor areas, and ignore measurement of volumes which are needed in various applications such as 3D Cadastre, taxation and valuation. It is expected that the IPMSs will be the dominant standard in the future, therefore the other measurement standards may take into consideration the IPMSs when updating their specification. The following stage of the research will focus on gathering feedback on the developed draft ontologies and validating them by using different validation approaches.

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