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Noise from plants systems and Building Information Modeling: The Code Checking

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ABSTRACT

The acoustic performance of buildings is increasingly a performance requirement required both in the construction of private buildings and public buildings. At international level, in recent years we have witnessed the revision and issue of new standards relating to the project phase (forecast calculation) of passive requirements based on the ISO 12354 series of standards. At the plant design level, the reference standard is represented by EN 12354-5 and ISO 16032 while in the post-operation verification phase the ISO 16032 and ISO 10052 standards are the reference for the measurements. One of the fundamental aspects to achieve high performance is to reach a level of design study that is increasingly detailed and shareable. Building information modeling, in addition to being an obligation for some types of work, is increasingly used by designers and construction companies, to have a better knowledge of the case on particular and methods of execution. The present work presents an overview of procedures that exploit the information of the BIM model for the predictive calculation of the acoustic performances of the systems, the verification of the legislative limits and the integration of the instrumental data recorded post-operam. The procedures were finally tested on a case study.

Keywords: Noise, plants systems, BIM

1. INTRODUCTION

The present work aims at analyzing the noise from building plants through the digitized procedures for buildings, [1-4] by applying them to test case which has been monitored in design, construction and final check stages [5-7].

Il Building Information Modeling (BIM) is becoming more widespread at international level as it brings considerable savings in time and money at different stages of building life. The BIM data format called Industry Foundation Classes, IFC, is an international open standard for BIM data [10] which are exchanged and shared among the software applications used by the various participants in the building sector or facility management. Such a standard includes definitions concerning required data for building in their life cycle. IFC 4.0 version extends and describes the definition of data for resources of the infrastructure during its own life cycle. Classes of IFC 4.0 format specify a database and a structure of exchange. As describes with BuldingSMART Europe [12], the database is defined in:

- EXPRESS language for data specification, defined in ISO 10303-11;

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- XML (XSD) scheme, defined in the recommendation for XML W3C scheme;

While the definition of the EXPRESS scheme is the source and the definition of XML scheme is generated with the EXPRESS scheme on the basis of mapping rules as defined in ISO 10303-28. Formats of swap files for data exchange and sharing are, according to the conceptual framework::

- Clear text encoding for structure of exchange, as defined in ISO 10303-21;
- Extensible Markup Language (XML), defined in the recommendation W3C XML.

Alternative formats for swap files can be used if they are compliant with databases. The 4.0 version of IFC includes databases, represented as an EXPRESS scheme and a XML schema, and reference data, represented as definitions of properties and quantities as well as formal and informative descriptions. A subset of database and of reference data is defined MVD (Model View Definition). A special MVD is defined to support on or more workflows that are recognized in construction industry and facility managements sectors. Each workflow identifies the requirements for data exchange meant for software applications. The compliant software applications have to identify the definition of the view of the model to which they conform . The aim of this study is to analyze information included in the IFC scheme as regards HVAC systems and plumbing a building can be endowed with by enhancing features and shortcomings for acoustic purposes . (BAM – Building Acoustic Model).

2. BIM IFC STANDARD AND PLANT SYSTEMS

This specification consists of a scheme defining data types, together with common concepts indicating the use of data types for specific scenarios. This section analyzes such common concepts which are applied to entities having a specific use in the context of buildings and generate noise of plant engineering nature. Such concepts form the basis of the views by BIM, which are supplementary specifications adapting setting and rules of this scheme to focused interventions within the building sector. Each model of concept defines a diagram for entities and attributes, with constraints and parameters which are set for special attributes and request types. Different entities within this scheme refer to such conceptual models and suit them to a special use on the bases of parameters. For instance the model of concept "Doors" defines the connectivity of the distribution system as regards mechanical, electrical and hydraulic systems; a pipe segment defines an application of the concept “Doors” having a door as input as well as a door as output. In the case of plant systems IFC 4.0 format, browsing among the different domains inside that are listed in the next section, defines two specific domains. The former called “IfcHvacDomain” for air conditioning systems and the latter called “IfcPlumbingFireProtectionDomain” for plumbing devoted to fire-fighting systems and water systems. Some entities and properties which are operated with these domains are sketched in figure 1 and 2.

2.1 IFC scheme “IfcHvacDomain” for HVAC plants

The IfcHvacDomain scheme defines the basic objects required to get interoperability within the heating, ventilation and air conditioning (HVAC). It expands the concepts defined in the IfcSharedBldgServiceElements scheme. The scope of IfcHvacDomain scheme is defined as:

- Segments, hoses and connections which form the distribution systems for the ducts and pipes typically used in the plants for buildings, as air conditioning plants, ventilation and exhaust air, service water, steam and water heating, drinking water, waste, natural gas and LPG systems, etc…
- Equipment typically used in systems for construction services, as furnaces, chillers , blowers and pumps and vibration isolation associated to this kind of components.
- Devices for flow and terminal control, as air intakes and grids, variable air controllers valves and shutters.

The following elements, are currently considered out of the scope of IfcHvacDomain scheme:

- Special industrial and institutional equipment as that used to produce and distribute electricity, etc…
- Provisions to treat hazardous materials as chemical or biological agents.
- System sequencing system checks for these facilities in addition to what is laid out in the scheme of the IfcBuildingControls domain.

2.2 IFC scheme “IfcPlumbingFireProtectionDomain” for plumbing

The IfcPlumbingFireProtectionDomain scheme is part of the Domain Layer of IFC model. It extends ideas regarding construction services which have been outlined in the

IfcSharedBldgServicesElements scheme. And it defines concepts in the plumbing and fire-fighting fields. The purpose of IfcPlumbingFireProtectionDomain, in conjunction with other schemes related to services for buildings, is the provision of hydraulic and fire-fighting services to buildings. In case of plumbing, the scope includes the provision of services outside the building until the gutter where the connection to the public network for drain/sewer is made. Special exceptions, in support of building code control have been provides as shown below. In case of fire protection systems, the scope includes all services from the node where they are connected to fire department or the point where the local water supplier delivers water supply (water meter). In detail the IfcPlumbingFireProtectionDomain scheme supports concepts that include the types of:

- sanitary elements for personal and public hygiene;
- traps on gas pipelines to prevent back flows and smell conveyance;
- interceptor to capture undesired liquids and solids and prevent their flow in drains;
- waste disposal units;
- ventilation as terminal and rainwater pipes at their highest level;
- automated and hand held terminals which can be triggered to put out the fire;
- hydrants that provide a water source for flexible pipes in the event of fire or other temporary water supply needs.

2.3 IFC Property Sets and Type

All plant entities defined in the IFC format are characterized by a set of data identified Property Sets for Objects [9,12], some of them are common to many entities while others are specific of the described entity. The task of Property Sets consists of describing how sets of data (usually defined with a name, value and unit of measurement or kind of data) are associated to objects or object types. For instance generation systems “IfcEngine” are defined in section 7.5.3.31 of IFC 4.0 scheme in buildingSMART [12] e described with Property Sets shown in the table of figure 1.”

PredefinedType	PsetName	Properties
-	Pset_EngineTypeCommon	-
-	Pset_SoundGeneration	-
-	Pset_ElectricalDeviceCommon	-
-	Pset_EnvironmentalImpactIndicators	-
-	Pset_EnvironmentalImpactValues	-
-	Pset_Condition	-
-	Pset_ManufacturerOccurrence	-
-	Pset_ManufacturerTypeInformation	-
-	Pset_ServiceLife	-
-	Pset_Warranty	-

Figure 1 – Property Sets for Objects ifcEngine

In addition to property sets entities are described by Types that is entity types to which relations that an entity (type) has with other entity types are referred (for instance a circulation pump with piping or toilet flushing tank with outflow pipe). By reference to an example with the use of IFC nomenclature, with “IfcEngineType” the kind of generator is described while with IfcDistributionFlowElementType” type the system type with which the generator is linked is described, for instance the distribution system. By way of example in the table of Figure 2 the types to which IfcEngine is linked are listed.

HasType	RelatingType	TypeName
-	IfcEngineType	-
-	IfcDistributionFlowElementType	-
-	IfcDistributionElementType	-

Figure 2 – object types applied to ifcEngine entity

Inside Property Sets, as can be deduced from names listed in figure 1, different data concerning plant systems performance are reported, under the terms of physical characteristics of components, but not only, i.e. as also information related to the sound generated by the component, to its warranty, to maintenance program, to environmental issues.

2.4 Encoding of objects

A fundamental role in digital processes, also in those used for acoustic purposes, is closely related to the classifications of all objects inside models. Classification systems serve to encode in an unambiguous manner objects, entities, processes, functions digitally operated. Worldwide there are several systems to classify processes of construction: among the best-known systems which have been fitted to the digital procedure UNICLASS, defined in UK by NBS institution, can be mentioned. NBS developed a set of tools linked to the digital world applied to constructions. Encoding is of paramount importance for acoustic issues both in the design stage for requirements and the finale stage of checking. In fact with a proper encoding accompanying the building just since its conceptual stage it is possible to analyze and handle the different plant entities and their interactions with entities of different type by setting all a series of rules for their own interactions which limit noise transmission and generation.

3. NOISE DATA OF PLANT ENGINEERING IN IFC FORMAT

From the point of view of the noise emitted and generated by the systems, the IFC format mainly includes two sets of data named "Pset_SoundAttenuation" (figure 3 [12]) and "Pset_SoundGeneration" (figure 4 [12]), within these PSets frequency values in Table form are referred to concerning sound attenuation and sound power emitted. The variables inside the two PSets are reported in the fiigures 3 and 4 in full.

Name	Type	Description
SoundScale	P_ENUMERATEDVALUE / IfcLabel / PEnum_SoundScale	Sound Scale -The reference sound scale. DBA: Decibels in an A-weighted scale DBB: Decibels in an B-weighted scale DBC: Decibels in an C-weighted scale NC: Noise criteria NR: Noise rating
SoundFrequency	P_LISTVALUE / IfcFrequencyMeasure	Sound Frequency - List of nominal sound frequencies, correlated to the SoundPressure time series values (IfcTimeSeries.ListValues)
SoundPressure	P_REFERENCEVALUE / IfcTimeSeries / IfcSoundPressureMeasure	Sound Pressure - A time series of sound pressure values measured in decibels at a reference pressure of 20 microPascals for the referenced octave band frequency. Each value in IfcTimeSeries.ListValues is correlated to the sound frequency at the same position within SoundFrequencies.

Figure 3 – Variables Pset_SoundAttenuation

Name	Type	Description
SoundCurve	P_TABLEVALUE / IfcFrequencyMeasure / IfcSoundPowerMeasure	Sound Curve - Table of sound frequencies and sound power measured in decibels at a reference power of 1 picowatt(10^(-12) watt) for the referenced octave band frequency.

Figure 4 – Variables Pset_ SoundGeneration

The variables included in the IFC format, in addition to serving as rated data of the plant components, can be used within the forecasting calculation models in the design phase, described by the UNI EN 12354 series (figure 7), with particular reference to part 5 [11].

3.1 The reference standards

The reference standards for plant noise can be divided into standards for the design of technical solutions, standards for the forecasting estimation of sound levels and, finally, standards for the measurement of plant noise.

The standard EN 12354-5: 2009. *Building acoustics - Evaluation of the acoustic performance of buildings starting from the performance of products - Sound levels due to technical instllations* is intended to provide a practical approach for estimating the sound level due to the installations and their influence on the soundproofing of a building, providing some indications on the proper installation modes. The standard is addressed to building acoustics experts. According to EN 12354-5, the results obtained through laboratory tests according to EN 14366 can be used for the preliminary determination of the sound power levels associated with the installations. The difficulty in preparing the document (which caused delay in its issue) is due to the following reasons:

- constructions provide for a high number of structural types;
- buildings provide for a high number of plant configurations, as well as construction techniques for installations very varied and sometimes chaotic .

The application of the calculation model is in any case very complex since the necessary data are difficult to find on the market and difficult to interpret. For the design of the discharge systems the reference is the European standard EN 12056 composed of 5 parts. Moreover for the analysis of the noise produced by installations the reference standards are:

- DIN 4109:1989 (together with DIN 52219:1993)
- UNI EN 14366:2004

They define the measurement methods and the evaluation of results. The main difference between the two test standards consists in the mass of the reference wall. DIN 4109 provides for 220 kg/m², while UNI EN 14366 provides for 250 kg/m². For the field measurements (in situ) of the plant noise the reference standards are:

- ISO 10052 Acoustics -- Field measurements of airborne and structure borne sound insulation and of equipment service sound -- Survey method;
- ISO 16032 Acoustics -- Measurement of sound pressure level from technical installations in buildings -- Engineering method.

These last standards were used to carry out in situ checks for the case study

4. PROCEDURES AND CASE STUDIES

The case studies consist of two buildings; the former is made respectively for the most part with a load bearing structure in CLT (cross laminated timber), formed with two bodies of the building, each with four flats. The two bodies of the building, are staggered due a different altitude but are alike as plant structure and distribution of spaces is concerned. The bodies of the building are shown in figure 5. The latter is made almost entirely in reinforced concrete and is a public building used as container of classrooms and offices at the University of Cagliari. Its modeling is shown in figure 6.

Figure 5 – case study 1 in steps: architectural BIM model, construction phase, work completed

4.1 Design e construction stage

The difficulties, already highlighted in section 3.1, found in obtaining input data to apply the prediction modeling described with EN 1235-5 led to use digital procedures to give to plant objects a whole range of performance requirements in order to reduce the noise and vibrations generated and conveyed by the building structure. In figure 6 the plant model for the two buildings is shown. Such a model, in addition to its capability to be populated with all the needed data for EN 12354-5 standard can be populated as well with a whole series of “dynamic” information which concern a differential behavior of objects and systems depending on how they are placed into the model and linked with other model (architectural, structural).

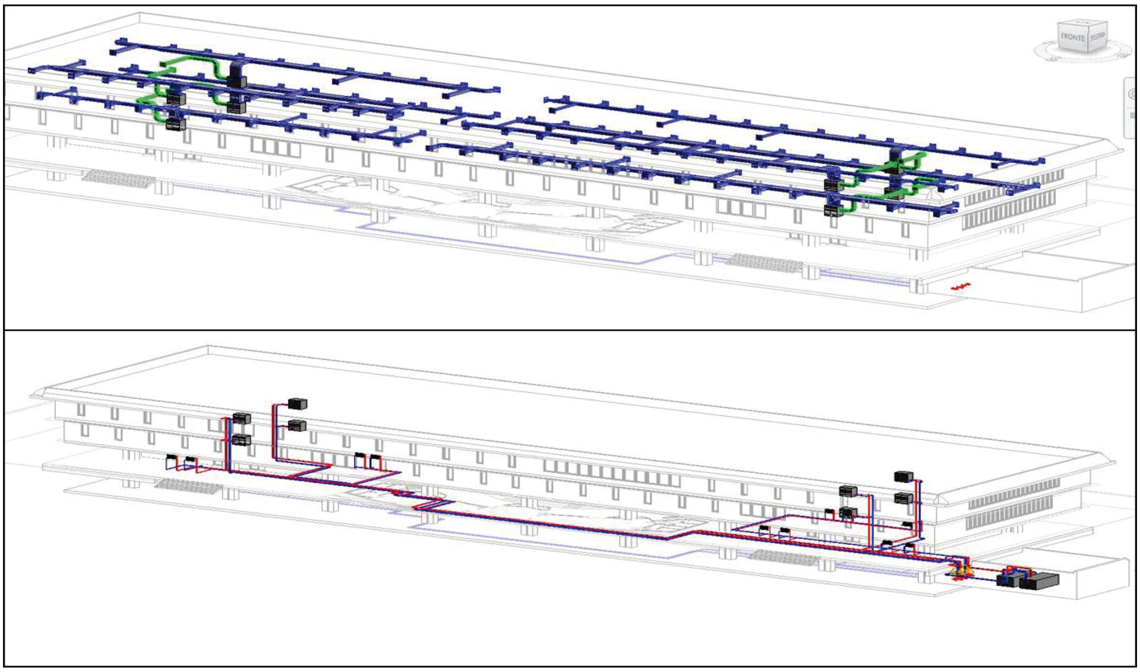

Figure 6 – Architectural and plant BIM model for case study 2

The design phase for acoustic requirements, demands that the model is populated with all a series of parameters that are specified in the reference standards. In figure 7 a flow diagram is shown, with the different quantities needed for the BPM designed to the acoustic calculation, stressing the minimum content and property sets that have to be included to allow for calculation.

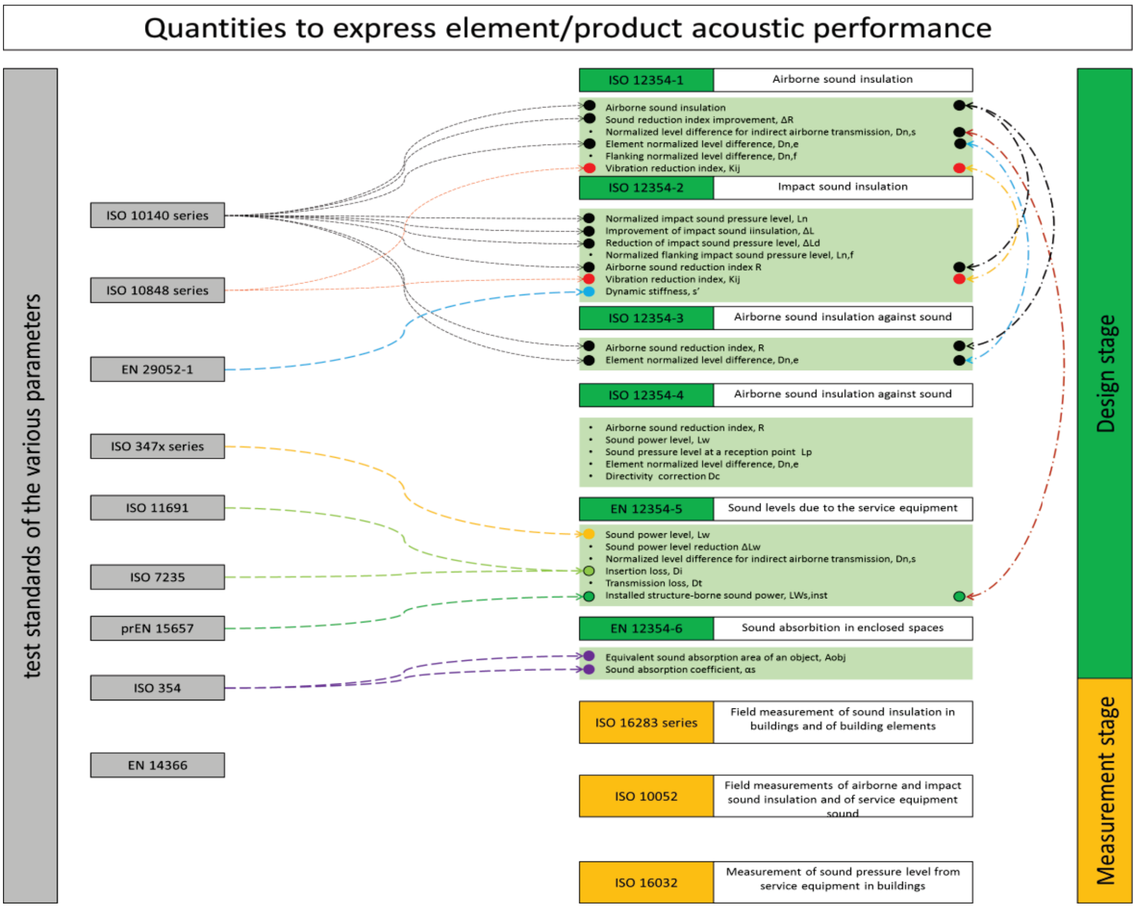

Figure 7 – flow chart and reference data standards for acoustic BPM or BAM

4.2 Testing phase at completed work

Tool check at completed work have been carried out by the reference standards [sec.3.1] exploiting the derived BAM to draw microphone positions and geometries concerning rooms where measurements have been performed. In this phase merging of different BIM models was carried out, as reported in figure 7, to allow for the study of interactions and for the building analysis aimed at applying survey procedures such as determining rooms where to perform measurements and drawing up digital survey sheets intended to a following stocking of acoustic data into the BIM model.

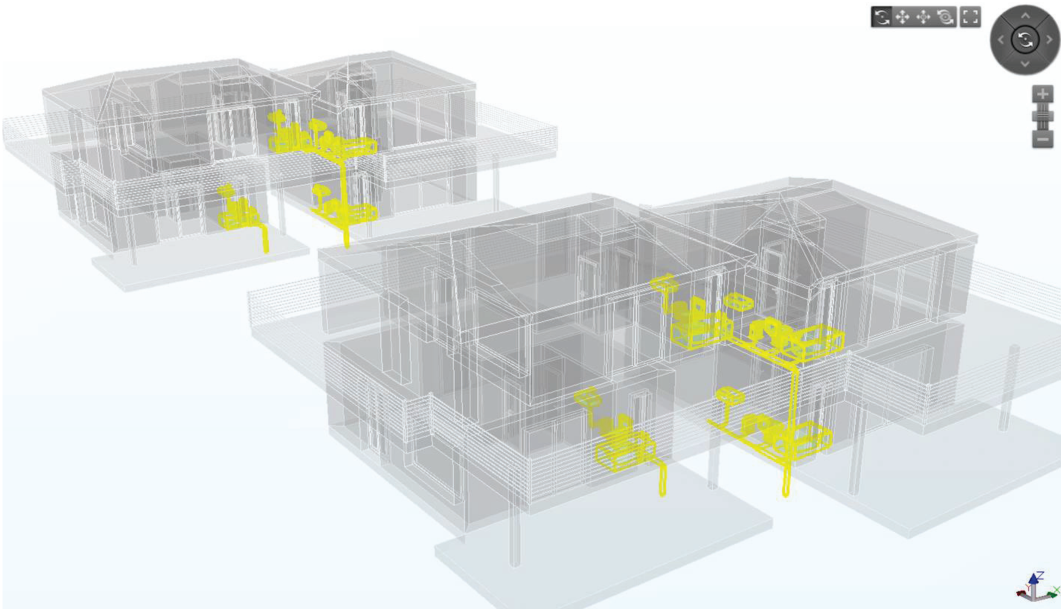

Figure 8 – merging of architectural and plant engineering BIM

The survey stage ended by associating the measured data to the digital model of the building. Such a stage is sketched in figure 9.

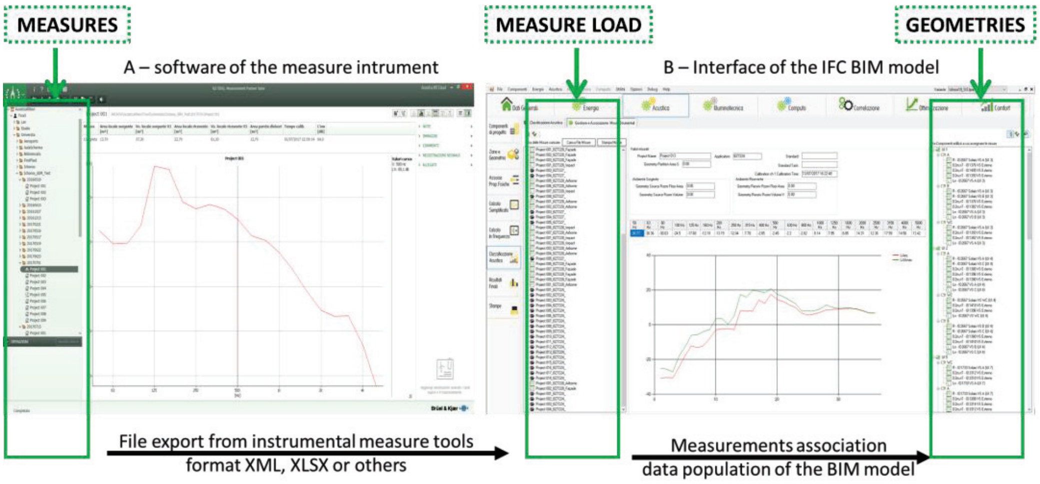

Figure 9 – Scheme to associate results of measurements to BIM model

5. CONCLUSIONS

In the present work BIM procedures aimed at their use as BPM for acoustic issues have been analyzed, more generally aimed at the use of information from BAM model (Building Acoustic Model), to ease the design procedure and instrumental verification in place.

From the analysis carried out about the data format IFC, recognized by ISO 16739 [p12] as BIM format, it was found that different data regarding the performance of plant systems and of a single component are not represented for each of them in such a format. This aspect, which could be taken as a not relevant shortcoming for the main aim of work management to which BIM is primarily addressed, according to author's opion plays a fundamental role in the informed choice of components by the operators and in the description of the potential of each component.

The proposal that we intend to carry on with the present work, is to put new Psets inside the standard, able to describe the performance of each single plant component; such inclusion would allow for the use of these data for design or analysis calculations, avoiding that each manufacturer placed on the market plant components with customized Psets which make it difficult to compare products for selection by designers. The standardization of performance parameters, would enable in any case, as IFC is an open format, all makers of components or plant systems to insert, in addition to standard parameters, the performance features of their products as already as is the case of building components.

In conclusion the presented work analyzed the IFC data format, focusing the attention onto the HVAC systems and plumbing. They were found to be detailed inside the data format by 66 typologies and several Sets of descriptors, many of which are common to the different described entities. As far as the variables needed to express energetic and acoustic performance are concerned, the above analysis pointed out the shortage of various parameters provided for the current standards of design. They could be integrated into the IFC format to make possible its use also for purposes related to performance calculations or to improve the mere performance comparison among the same entities.

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