URBEM

Understanding the archetypes: a guideline

1. Introduction

URBEM (Urban Reference Buildings for Energy Modelling) is a research project funded by the Italian Ministry of University and Research (MUR) in the framework of PRIN 2020 (code 2020ZWKXKE).

URBEM has the scope of providing a national database for reference buildings to be used by UBEM (Urban Buildings Energy Modelling) tools. The partners established a sound methodology based on the consultation of available databases at national, regional and local level, concerning building fabric, building systems and energy use, by also complementing existing archetype databases (e.g., TABULA project) and adapting them to the specific needs of UBEM tools. Data availability has been through alternative data sources, including open data, and the use of any data related to buildings and users collected for any purpose, such as building permission and research projects. The collected data underwent data cleaning and reduction, and were statistically analysed to get a picture of the average performance of the buildings stock in:

- Various building types
- Various periods of construction
- Various Italian regions
- Various Italian climate zone

This work led to the creation of a series of "scorecards", each describing the features of a building archetype. The scorecards are available on the URBEM website; this document is a guideline to understand the data included in the scorecards.

2. Archetype classification

Each archetype is identified through a code that is built according to the following structure:

ID1_ID2_ID3_ID4_ID5

- The first identifier (ID1) regards the intended building use. Annex 1 of this document reports all possible intended building uses and the corresponding ID1 code, coherently with both the National Annex of Standard UNI EN ISO 52000-1 (Table NA.4) and the Presidential Decree (DPR) 412/93. The following codes have been used for ID1 in URBEM:
    - RES = Residential
    - OFF = Offices
    - EDUC = Educational
    - COMM = Commercial
    - CATR = Catering
- The second identifier (ID2) adds information about the building type. For instance:
    - APPBLOCK = Apartment blocks
    - SINGLE = Single dwellings
    - TEMP = Temporary dwellings (e.g., holiday homes)
    - BLDGS = Entire buildings
    - DEPT = Department stores

- The third identifier (ID3) specifies the period of construction of the buildings included in the archetype. For instance:
  - 1961-1970 = from 1961 to 1970
  - -1900 = before 1900
  - 2005- = from 2005 on
- The fourth identifier (ID4) indicates the climatic zone that the archetype refers to (from A to F according to the Presidential Decree (DPR) 412/93).
- The fifth identifier (ID5) identifies the geographic area that the archetype applies to:
  - SIC = Sicilia
  - CAL = Calabria
  - LOM = Lombardia
  - PIE = Piemonte
  - VAL = Valle d'Aosta
  - TUS = Toscana
  - TN = Provincia Autonoma di Trento
  - LAZ = Lazio
  - APU = Puglia
  - ITA = entire national territory

3. Clustering methodology

3.1 Variables identification and statistical analysis

The variables included in the archetypes can be divided into **numerical variables** and **categorical variables** (i.e., variables that do not have a numerical value).

As far as **categorical variables** are concerned, they can only assume specific entries, which are specified in Annex 2. In this case, the archetypes report the percentage distribution of the various recurring entries for each categorical variable: the tables show only the three most recurring entries, while possible other values are referred altogether as "Others". The detail of the entries included in "Others" is available at the bottom of the page.

As far as **numerical variables** are concerned, the statistical distribution of their values is described through the mean value, the median, the first and the third quartiles, and the standard deviation: all these data are reported in the tables. Moreover, the distribution is graphically represented through a series of boxplots: here, each vertical box identifies the interquartile range, i.e., the range limited by the first (lower) and the third (upper) quartiles, while the horizontal segment inside each box is the median value of the distribution. The whiskers (vertical lines) include the entire range between the minimum and the maximum values, defined after taking out the outliers (represented as circles, if any)[1]. The diagrams also include a small cross representing the mean values. Please consider that, when no values are available for a certain numerical

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[1] It is here worth recalling that the outliers of a population are those individuals that deviate either from the upper or from the lower quartiles by more than 1.5 times the interquartile range.

variable, the corresponding cell in the tables is filled with hyphen (-) and the corresponding boxplot is void (a marker may appear at zero value).

3.2 Data processing and cleaning

Before processing the available data, a simplified "data cleaning" procedure has been operated to identify, and remove, those records that can be considered incorrect and unreliable. The following criteria were adopted and applied to each record (i.e. each building):

- the ratio of the heated gross volume to the heated gross floor area must fall within the range defined as gross height ± 10 cm
- the ratio of the heated net to the heated gross volume must fall between 0.55 and 0.85
- the *Compactness Ratio* (heated building envelope surface to heated gross volume) must fall between 0.2 and 1.2
- the *Window-to-Wall Ratio* (WWR) values must fall between 0 and 1 for each orientation
- the U-values of the various structures must be physically reasonable:
  - <u>Walls</u>: between 0.15 and 2.8 $W \cdot m^{-2} \cdot K^{-1}$
  - <u>Roofs and floors</u>: between 0.15 and 3 $W \cdot m^{-2} \cdot K^{-1}$
  - <u>Windows</u>: between 0.7 and 6.5 $W \cdot m^{-2} \cdot K^{-1}$
- The "Air exchange rate" – if available – must be > 0.25 h^{-1}

Moreover:

- If the entry "Heating System Type" is "Absent", all the following conditions must be true:
  - "Heating generator" = VOID
  - "Heating emission sub-system" = VOID
  - "Total Heating Power" = 0 (or VOID)
- If the entry "Cooling System Type" is "Absent", all the following conditions must be true:
  - "Cooling emission sub-system" = VOID
  - "Total Cooling Power" = 0 (VOID)
- If the entry "DHW Generator" is "Void", then "DHW System Power" must be = 0 (or VOID)

Finally:

- If, for a given record (i.e., a given building), <u>only one of the listed conditions was not met</u>, the entry affected by the error was deleted from the record.
- If, for a given record (i.e., a given building), <u>more than of the listed conditions was not met</u>, the entire record was deleted, since it can be considered unreliable.

4. Comments about the data included in the archetype

- "<u>Number of records</u>" indicates the number of buildings that have contributed to build the archetype.
- "<u>Data sources</u>": the type of "sources" that were consulted to retrieve the data, with the corresponding percentage of records belonging to each type.

- "<u>Description</u>": a synthetic typological description for the most recurrent external walls and roof slabs in the archetype (e.g., "non-insulated perforated brick wall"). An alphanumeric code identifies the structure in the UNI/TR 11552:2014. In addition, one can find the thickness of the insulation – if any – corresponding to the median U-value associated with the structure. In case the description of the structure does not correspond to any of the structures reported in UNI/TR 11552:2014, a hyphen (-) is used, meaning "non-available data".

- "<u>Roof Type</u>" identifies the type of roof of the building even when the building has an unheated attic, since UBEM software tools are not usually able to represent the presence of unheated spaces.

- "<u>Compactness ratio</u>": the ratio of the heated building envelope surface to the heated gross volume.

- "<u>WWR</u>": the ratio of the window surface area to the entire façade area, for each orientation.

- "<u>Gains and Ventilation</u>": when the data here included could not be retrieved from any of the sources, the corresponding field reports the section of the UNI EN 16798-1 (National Annex) where a reference value can be retrieved for simulation purposes. In this case, an asterisk is also added.

It is also important to underline that in the UBEM software tools only the geometrical data for the entire building are relevant. In case the geometrical data retrieved from the sources refer to the apartment scale, these data are reported in a separate section on page 3 of the scorecards, called "Additional data". Instead, page 1 only includes geometrical data referring to the building scale: when these are not available, the corresponding fields are populated with hyphens (-).

However, such distinction between apartment scale and building scale is only necessary in the "Residential" category. In all other cases, page 3 will not include any geometrical data.

Still on page 3, some data about the thermal systems are shown in the "Additional Data" section: an asterisk is used to specify whether these data refer to the building scale (centralized systems) or to the apartment scale (autonomous systems). The efficiencies of the thermal systems have not been reported because, when available, they would refer to unclear boundary conditions and therefore would not be comparable or usable in UBEM software tools. Defining these values is therefore left to the UBEM operator, also based on real datasheets.

ANNEX 1 – Intended building use and corresponding identifiers

#	Description	DPR 412/93	Building category
1	Single-family houses of different types	E.1(1)	
2	Apartment (in a multi-family block)	E.1(1)	
3	Entire multi-family block	E.1(1)	
4	Homes for elderly and disabled people	E.1(3)	*Residential (RES)*
5	Residence for collective use	E.1(1)	
6	Mobile home	E.1(1)	
7	Holiday home	E.1(2)	
8	Office - Short working week	E.2	*Offices (OFF)*
9	Office - Long working week	E.2	
10	Primary schools short staying	E.7	
11	Primary schools long staying	E.7	
12	Secondary schools short staying	E.7	*Educational (EDU)*
13	Secondary schools long staying	E.7	
14	University classrooms	E.7	
15	Hospitals with overnight stay	E.3	*Hospitals (HOS)*
16	Day hospital	E.1(3)	
17	Hotels	E.1(3)	*Hotels (HOT)*
18	Restaurants	E.4(3)	*Catering buildings (CATR)*
19	Bar	E.4(3)	
20	Swimming Pools	E.6	*Sport buildings (SPO)*
11	Sport buildings	E.6	
22	Department stores and shopping mall	E.5	*Commercial buildings (COMM)*
23	Retail stores	E.5	
24	Factories	E.8	
25	Data center	E.8	*Industrial and agricultural buildings (IND)*
26	Warehouse	E.8	
27	Workshops	E.8	
28	Agricultural	E.8	
29	Cinema, theatres, conference buildings	E.4(1)	
30	Museums, exhibition's halls	E.4(2)	
31	Religious buildings	E.4(2)	*Place of assembly (ASS)*
32	Libraries and reading rooms	E.4(2)	
33	Dancing halls and discos	E.4(3)	

ANNEX 2 – Possible values for the categorical variables

Roof type	External walls type	Slab on ground floor type	Windows type	Shading system type
Brick-concrete slab	Concrete wall	Brick-concrete slab	Double glazing, PVC frame	Curtains
Reinforced brick-concrete slab	Hollow brick masonry	Concrete floor	Double glazing, wooden frame	Roller blinds
Reinforced brick-concrete slab (low insulation) *	Hollow brick masonry (high insulation) *	Masonry with lists of stones and concrete	Double glazing, aluminum frame with thermal break	Shutters
Reinforced brick-concrete slab (medium insulation) *	Hollow brick masonry (low insulation) *	Reinforced brick-concrete slab	Double glazing, aluminum frame, no thermal break	No shading
Reinforced brick-concrete slab (high insulation) *	Hollow brick masonry (medium insulation) *	Vault floor with bricks and steel beams	Single glazing, aluminum frame	Unknown
Wood structure and planking with tiles	Masonry with local stones	Ventilated crawl space	Single glazing, PVC frame	
Unknown	Prefabricated panels	Unknown	Single glazing, wooden frame	
	Reinforced brick-concrete wall		Triple glazing, aluminum frame with thermal break	
	Reinforced brick-concrete wall (high insulation) *		Triple glazing, PVC frame	
	Reinforced brick-concrete wall (low insulation) *		Triple glazing, wooden frame	
	Reinforced brick-concrete wall (medium insulation) *		Mixed	
	Solid Brick masonry		Unknown	
	Basalt or Trachyte masonry			
	Limestone or marl masonry			
	Granite masonry			
	Metamorphic stone masonry			
	Low density stone masonry (dry density up to 1300 kg/m³)			
	Medium density stone masonry (dry density from 1300 to 2000 kg/m³)			
	High density stone masonry (dry density from 2000 kg/m³)			
	Raw earth masonry			
	Unknown			

* <u>High</u>:   U < 1.2 · (max U-value admitted by Decree 26 June 2015 in case of energy renovation)
* <u>Low</u>:   U > 2 · (max U-value admitted by Decree 26 June 2015 in case of energy renovation)
* <u>Medium</u>: otherwise

Type of ventilation	Heating system type	Heating generator	Heating emission sub-system	Energy carrier
Mechanical	Absent	Air-source heat pump	Air Heater	Biogas
Natural	Autonomous	Boiler (unknown type)	Convectors	Coal
Mixed	Centralized	Condensing Boiler	Fan coil	District cooling
Mechanically activated natural ventilation	Unknown	Traditional Boiler	Mechanical ventilation vents	District heating
Unknown		Fireplace	Radiant panels	Electricity
		Ground-source heat pump	Radiators	Electricity from PV, wind turbines, hydraulic turbines
		Heat exchanger of district heating or cooling	Unknown	Gas Oil
		Water-source heat pump		Liquid and gaseous biomass
		Unknown		LPG
				Natural Gas
				Solid biomass
				Thermal energy from solar collectors
				Unknown

Cooling system type	Cooling emission sub-system	DHW system type	DHW generator
Absent	Chilled beams	Autonomous, coupled with heating	Electric boiler
Absorption chiller	Fan coil	Autonomous, detached from heating	Natural gas boiler
Air-cooled chiller (split unit)	Mechanical ventilation Vents	Centralized, coupled with heating	Electric Heat Pump
Water-cooled chiller	Multi-split	Centralized, detached from heating	LPG boiler
Unknown	Passive chilled beams	District heating	Solar thermal
	Radiant panels	Unknown	Unknown
	Unknown		