

A METHOD FOR THE GENERATION OF MULTI-DETAIL BUILDING ARCHETYPE DEFINITIONS: APPLICATION TO THE CITY OF LISBON

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ABSTRACT

In Europe, buildings are responsible for 40% of energy consumption and about 35% of the current building stock is over 50 years old. A significant part of this energy consumption is determined by the buildings' characteristics. However, cities are complex systems with a diverse and very large number of buildings and, as a consequence, the quantification of energy consumption in the existing building stock requires the characterization of a set of buildings types that may represent most of the built urban environment.

It is therefore necessary to limit the number of building types to analyse, in a compromise between feasibility and accuracy. As such, there is a need to establish methods that define sets with limited numbers of building archetypes, but that are still able to represent the entire building stock. Furthermore, it is important to understand which restrictions can limit the development of these classifications.

This paper presents a method intended to characterize archetypes for an effective simplification of the modelling of the urban built environment. The method enables the development of different levels of classification of the built environment. This classification is dependent on the available data and documented sources, as well as on the definition of several parameters related with the final model goal.

The result of the method is an archetypal tree-data structure with a set of detail dependent archetype tiers, that allow structuring the building stock typification as a base for the evaluation of urban modelling techniques and their uncertainty.

The method is applied to the city of Lisbon. The results show how much the building stock characterization can be simplified and how many building types should be considered. In particular, it proves how the creation of archetypes depends highly on the level of detail of the considered parameters and the availability of reliable data. As a final product of this work, a complete dataset of building archetypes for Lisbon is provided, as well as a set of recommendations for improving or expanding existing urban information.

Keywords: Building Stock, Building Archetype, Urban Modelling

INTRODUCTION

The opportunity to improve the overall energy performance of buildings through retrofitting strategies is increasing and becoming more important, once the building stock, mainly in developed cities, is getting old and corresponds to a large share of the built environment. Additionally, the Energy Performance of Buildings Directive [1], established clear guidelines

for the promotion of energy efficiency in buildings up to 2020 and further, constituting an opportunity for the existing building stock to become more energy efficient.

The building stock, even at city scale, is very large and diverse, making it necessary to limit the number of buildings to analyse, in a compromise between feasibility and accuracy. Therefore, the classification of a set of building-types which represent the characteristics of large groups of buildings in the stock is required.

The building stock can be described in categories of sample buildings and/or archetypes, and the literature provides several descriptions of the building stock for several EU countries with the purpose of modeling its energy demand [2]. Stock modelling based on archetypes is considered a promising tool for exploring resource and emissions reduction. It is particularly helpful in stock aggregation with the potential of analyzing the existing stock and can be used to make scenarios of energy retrofit measures and future projections [3].

Building archetypes are theoretical buildings created by a composite of several characteristics found within a category of buildings with similar attributes. Therefore an archetype is a virtual representation of a number of buildings that share similar characteristics in the stock.

In this study is proposed a new methodology with a qualitative approach to archetypes' construction for compiling, structuring, validate and representing the information of the existing building stock. This paper describes the building stock typification as basis for urban models, namely a) reviewing the existing methodologies, identifying key issues as data input and sources of information; b) describing a new methodology for building stock typification applicable at different scale levels and for different purposes and c) applying the proposed method to Lisbon city.

METHODOLOGIES FOR BUILDING STOCK TYPIFICATION

Supplementing EPDB, the commission guidelines [4] on the energy performance of the buildings establish that reference buildings should be defined using one of the two following ways: selection of real example building or the creation of a virtual building. According to [5] [6] [7] [8], the typification of the building stock, as reference buildings or buildings typologies, can be summarized by the following three methodologies:

- *Real Building Methodology*: selection of a real existing building representing the most typical building in a specific category. The selection process is performed through a statistical analysis in order to find out the real building with characteristics similar to the mean geometrical and construction features of the statistical sample.

- *Example Building Methodology*: creation of a virtual building which for each relevant parameter includes the most commonly used material and systems on the basis of expert inquiries and other sources of information - no statistical data available.

- *Synthetical Average Building Methodology*: creation of a virtual building which for each relevant parameter includes the most commonly used material and systems using basic statistical data; Statistical composite of the features found within a of buildings in the stock.

Table 1 outlines several publications focusing on the typification of building stock for energy models purposes. The most common methodology used is the Synthetical Average since it relies on statistical data analysis. Still, there are some studies that combine two methodologies in order to overcome the lack of information in some parameters. However, studies that combine all the methodologies applied to the Portuguese case were not found.

Paper	Concept			Method			Parameters				Scale			Scope
	Bld Typology	Reference Bld	Archetype	Real Building	Example Building	Synthetical Average	Climate Zone	Constr. Period	Bld Type	Other Parameters	National	Regional	Urban	
[5]		X			X	X	X	X	X	X			X	residential
[2]			X			X	X	X	X	X	X			resid/non-resid
[9]	X					X	X	X	X	X		X		residential
[7]		X			X	X	X	X	X	X		X		residential
[10]	X				X		X	X	X	X	X			residential
[11]	X			X		X		X	X	X	X			residential
[12]	X			X		X	X	X	X	X	X			residential
[6]		X			X	X	X	X		X	X			office
[13]		X		X		X		X	X	X			X	residential
[14]	X				X		X	X	X	X	X			residential
[15]	X					X		X		X	X			residential

Table 1: Literature Review of Building Stock Typification Studies

Climate Zone, Construction Period and Building Type are usually the parameters that serve as selection criteria for the building stock segmentation. Still, there are other parameters that must be defined and detailed in order to build the energy model. These additional parameters can be divided into four different sets, based on DOE's report [16]: Geometry (form), Construction (fabric), Systems (equipment) and Operation (program). The parameters definition for each set is dependent on the chosen energy model data requirements. For other modelling purposes, other selection and additional parameters sets can be established without compromising the building stock typification process.

Regardless of having several studies applying the methodologies described above, there is no agreement in a common approach between the definition of reference buildings and the existing buildings' data, which is creating several problems at national and European level [6] [7]. As a result, the *TABULA (Typology Approach for Building Stock Energy Assessment)* project effectively made the effort of constructing a European database of building typologies sharing the same approach, by presenting a methodology for the identification of reference buildings focusing on residential building types. Studies 7, 10, 11, 12, and 14 presented in Table 1 follow the *TABULA* approach, which counts with the data of 13 participating countries as part of its building typology database. The proposed *TABULA* methodology is therefore the reference used in Europe for building stock typification in energy demand studies.

This methodology displays the building typologies in a 'building typology matrix' for a specific climate zone and use. The matrix is characterized by two axes, namely the building age class and the building size class. Each cell in the matrix contains a reference building type that is a building considered representative of that specific condition. This categorization procedure may not be most appropriate and can be considered rigid since it is represented by a bi-directional matrix with fixed parameters as the period of construction and building size-class.

The process of categorization is very complex and its accuracy will rely on the level of detail of the building-types. Although *TABULA* does not constrain the methodologies that can be used in simultaneous, the majority of the studies based on this approach rely on one or sometimes two methodologies.

Define buildings-type accurately is important to achieve realistic results and therefore the use of all methodologies in simultaneous allows the access to more data from different sources and can overcome the problem of lack of data in building-types categorization.

METHOD

This paper presents a new method for the identification of building-types, which is innovative in two important points. First, it is a mixed method since it combines all the methodologies described before. For each relevant parameter, it includes as input statistical, empirical and real data. All the sources of information available are considered, allowing a more complete characterization of the existent building stock in archetypes and accurate energy estimation. Second, the information is structured using a data-tree arrangement instead of a matrix, working as decision analysis and giving more flexibility in the building categorization. Important insights can be generated based on experts through changes in the order of the tiers of archetypes, adapting the model to the real case-study and identifying the better strategy to reach a specific goal. It also allows new possible scenarios for archetypes definition through the addition or through different combination of the selection parameters.

The methodological approach is divided into the following steps (Figure 1):

1 – *Parameters Definition*: All the parameters needed for the model are identified. The parameters used depend on the goal of the study and the chosen model to materialize it.

2 – *Categorization*: Considering the previous list, define which parameters are considered as Selection Parameters. Selection Parameters are those which will serve as base criteria to define the different tiers in the data-tree. The number of selection parameters corresponds to the number of detail tiers.

3 – *Data-Tree*: Based on the number of tiers, define the order. Each tier represents the outcome for the selected parameter and each node represents the corresponding archetype.

4 – *Characterization*: Define all the parameters for each Archetype in the selected tier. Compare the attributes to avoid redundancy between archetypes and eliminate the ones not required before passing to the other tier. As final result, a database of archetypes with all parameters characterized according to the order of selection parameters defined previously is constructed.

5 – *Archetypes Frequency*: Definition of weighting factors for the archetypes in order to quantify the number of existing buildings applied to each class. A GIS map allocating spatial information and the archetypes characteristics can also be developed.

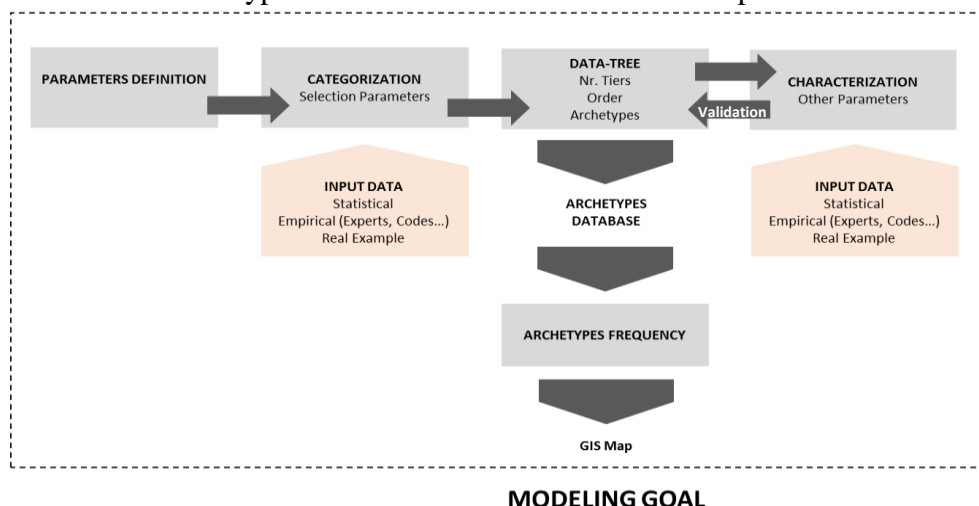


Figure 1 – Typification of Building Stock Methodology

CASE-STUDY

Lisbon City was selected as case-study to demonstrate the methodology. A restricted area within the urban territory was defined here, however the methodology can be applied at urban, regional or national scale. The archetypes characterized will be used for modelling the environmental performance of the neighborhood and city with respect to operational and embodied energy use, walkability and daylighting potential, using UMI – Urban Modelling Interface, a tool developed by the Massachusetts Institute of Technology team.

Considering this tool, the parameters needed for the model were identified. The selected parameters included the climatic zone, the main use, the period of construction and the roof type, since these are the parameters that bring higher variability to the model. After the last tier outcome, the other parameters remain relatively constant not justifying more detail.

RESULTS

The following figure exemplifies the archetypal data-tree for this case-study. For the selection parameters 3 tier of detail were determined resulting in 13 archetypes for this neighbourhood. The data-tree arrangement allows the user to set the boundaries regarding the energy model goals and compare results when considering a specific aggregation of parameters or all of them. Therefore, the presented archetypes are options for decision making allowing the test of different scenarios. Also, the graphical representation enables a better comprehension of the relations between parameters and a critical view of the quality of the outcome. This methodology is flexible enough to integrate more parameters and consequently more detail into the model without compromising the archetypes already set before.

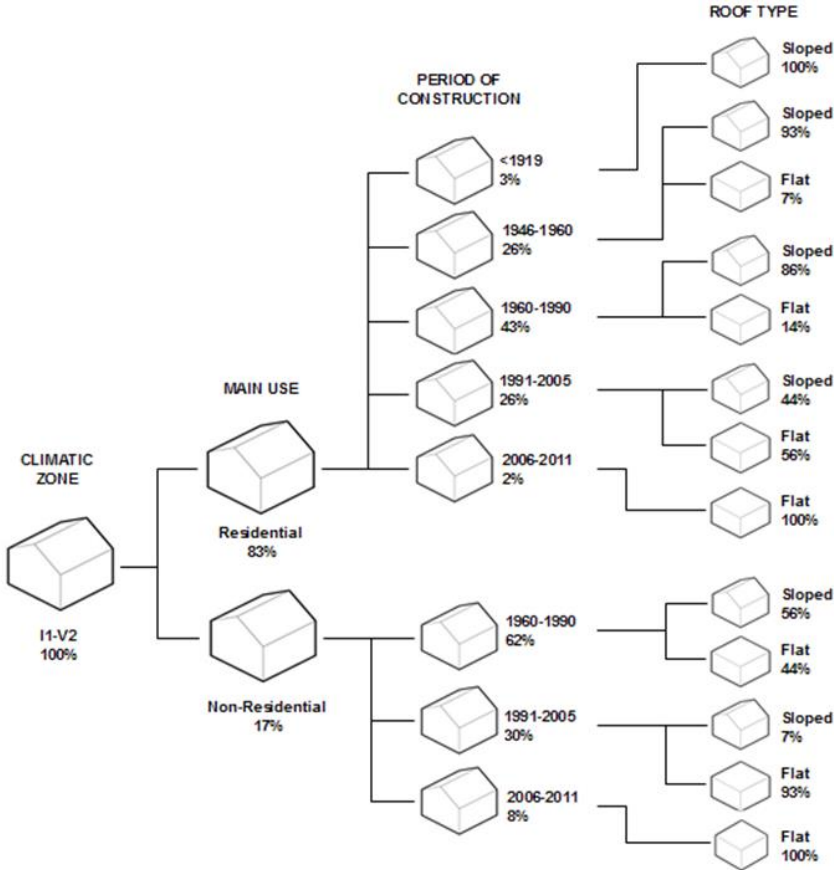


Figure 2 – Archetypal Data-Tree – Lisbon Case-Study

CONCLUSION AND FUTURE WORK

This paper presents a new methodology for the development of archetypes that characterize the existing building stock. This can be used for studies on building energy performance, LCA, risk prevention and policies towards effective refurbishment measures, among others. It is a hybrid method since it combines several methodologies, which results in the use of more complete input data, increasing the model accuracy without compromising its feasibility.

As a result, this new methodology reduces uncertainty related with the building stock typification since it considers several sources of information and several parameters detail. The goal is to provide the most complete and comprehensive framework of the archetypes

able to represent the existent building stock. The data-tree structuration proved to be a useful representation in the typification of a large number of buildings, with different sizes and complex characteristics. The number of archetypes required to accurately represent the building stock differs considering the detailing and differentiation pretended. The final number of archetypes achieved changes with the variation on the selection parameters, depending on how is established the cutting criteria line.

Further investigation involves an identification of the most relevant variables which explain energy use through a statistical parametric analysis able to identify and rank the key parameters and the development of archetypes based on that. Thus, it will be possible compare this method with the one presented in this paper and analyse the modelling results when considering a quantitative versus a qualitative approach in archetypes data-tree construction.

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