



RAZVOJ METODOLOGIJE ZA FORMIRANJE TIPOLOGIJE ŠKOLSKIH ZGRADA U SRBIJI

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Abstract:

Nakon razvoja i definisanja Nacionalne tipologije stambenih zgrada Srbije, isti istraživački tim sa Arhitektonskog fakulteta univerziteta u Beogradu razvio je i metodologiju za formiranje tipologije školskih zgrada. Za ove potrebe, definisan je poseban postupak prikupljanja podataka, kreiran upitnik i sproveden popis školskih zgrada. Dobijeni podaci predstavljaju deo baze javnih zgrada, i korišćeni su za potrebe formiranja tipologije školskih zgrada, kao i procene energetske performansi javnih zgrada u okviru projekta EmBuild (Horizon2020). U radu su prikazane i objašnjene metodologije formiranja baze podataka i njihovog prikupljanja, kao i metodologija formiranja tipologije školskih zgrada.

Keywords: javne zgrade, unapredjenje energetske efikasnosti, tipologija, školske zgrade

METHODOLOGY DEVELOPMENT FOR CREATION OF SCHOOL BUILDINGS TYPOLOGY IN SERBIA

Abstract:

After development of methodology for formulation of residential building typology, the same research team from the Faculty of Architecture University of Belgrade developed and formulated the methodology for typology of school buildings. For this purpose, specific method of data acquisition was designed and conducted. Obtained data represent part of the public building database and were further used for defining typology of school buildings, as well as estimation of energy performance of public buildings within EmBuild project (Horizon2020 framework). In the paper the methodology of creating this database and gathering information, as well as further work on definition and final typology of school buildings are presented.

Keywords: public buildings, energy efficiency improvement, typology, schools buildings

INTRODUCTION

As the member of Energy community, Serbia has the obligation to renovate 1% of public buildings stock owned and used by the central government while according to EC Directive it should be 3% for other EU member states. The incentive to research the quality of public buildings was provided by the fact that they, along with residential buildings, account for the largest share of the country's building stock and that their deep renovation can greatly reduce energy consumption and carbon dioxide emissions. Also it is expected that public building refurbishment induces refurbishments in residential sector and includes a whole range of wider benefits: economic savings, better work environment, less health problems, local economy development, raising awareness about energy efficiency etc. Long term investment mobilization in public sector is expected to be defined through National renovation strategy, which was due in October 2017. First public buildings that were investigated were educational buildings - schools and kindergartens, through the method of typology.

The same research team from the Faculty of architecture University of Belgrade that developed the methodology for residential buildings and published several monographs on this subject, this time supported by the researchers from Faculty of mechanical engineering and Faculty of mechanical engineering, developed principles and methodology for the school buildings field survey and typology formulation. As the previous work on typology of residential buildings, this research project Energy Efficiency in Public Buildings was also supported by the GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit). The collected data are also used for Horizon2020 EmBuild project (Empower public authorities to establish long-term strategies of renovation of public buildings) for the development of long term renovation strategies on local level.

Although EU Directive [1] defines the obligation of EU members to renovate the public building stock, no detailed researches about characteristics of public buildings is published yet. An overview of several building stock models and their classification and characterization is found in literature [2], as well as new model proposals [3]. The greatest number of published papers analyses and discusses typologies for residential buildings [4] [5] [6]. Faced with the lack of published public building typologies, the decision of the coordinators of the team was to rely on their own experience in developing different residential building typologies on local and state level [7] [8] [9] [10], and vast literature and legislation research on the characteristics of public buildings, especially educational buildings: schools and kindergartens.

1. SCHOOL BUILDINGS IN SERBIA

The basic condition of any valid statistical analysis, as the basis for typology formulation, is the database with reliable data and with the necessary number of entries. Regarding information on public buildings, there is no uniform and comprehensive list of Serbian public buildings. Regarding educational buildings, there are several databases publicly available:

- The Statistical Office of the Republic of Serbia regularly publishes updates on its activities on its website. School buildings are covered in several sources: as Statistical Yearbook of the Republic of Serbia – Education, published annually, [11] and within the Communiqués: Primary School Education in the Republic

of Serbia and Secondary Education in the Republic of Serbia, [12] published at the beginning and end of each school year.

- The Ministry of Education, Science and Technological Development of the Republic of Serbia also publishes data on schools and school buildings in Serbia [13].

As it was noticed that neither of the sources contained defined building characteristics (characteristics of thermal envelope) and characteristics of mechanical and electrical systems necessary for typology and energy characteristics definition, it was concluded that a comprehensive survey should be conducted.

1.1. SCHOOL BUILDINGS SURVEY

The inventory of school buildings was compiled in 2016 and 2017. For this purpose, Serbia was divided in 6 regions and for each region a group of experts was established. The basic idea was that beneficiaries, public officers and energy managers in municipalities have enough data and knowledge about public buildings on the territory of their municipalities. In practice, the support from the experts was needed on several occasions and some questionnaires were filled by the employees of the public building in question. Such a situation resulted in several questionnaires that were not filled or were filled with incorrect data. Later, the obtained data were entered into a specially created database (not publically available) and then retrieved, processed and searched using custom-designed software.

1.1.1. The questionnaire

The questionnaire consisted of 78 questions divided in several groups:

- The first level of the questionnaire with five questions identified public bodies. In practice, one public body could dispose with several independent buildings on different locations. When school buildings are in question, one school can have several smaller, district schools under its jurisdiction.
- The second level with 14 queries specified the location (address, cadastral parcel municipality, number and sub number) and basic data about the building: when it was built, whether it was purpose-built, whether an energy efficiency study or energy audit were conducted, and whether it was issued the Certificate of Energy Performance of Buildings (energy passport);
- The third and most comprehensive level had 48 questions. It included three sets of questions regarding: architectural characteristics of buildings relevant for its energy efficiency (shape and size of the building, number of floors, type of roof, type of windows, external walls, floors, and ceiling characteristics...), mechanical installations (type of the heating system, type of the boiler, fuel type, boilers for preparation of sanitary hot water...) and which was filled only for schools and kindergartens, and which included the architectural characteristics of the building as well as the applied mechanical and electrical installation systems.
- Special part of the data base consisted of photographs of the school buildings. Those photographs were used for cross checking of the entered data and for choosing the real building which is the representative of the model building.

After the compilation of the inventory, the formation of the database and the validation of the data, it was found that a sample of 1,857 school buildings was formed. As according to the Statistical Office of the Republic of Serbia [11] Serbia has 3890 school

buildings, it was concluded that the number of surveyed buildings entered into the database represents a representative sample and that can be the basis for making valid conclusions.

1.1.2. Size and year class of school buildings

In order to define the basic typology matrix for school buildings several factors were investigated and considered. The research team analysed the development of school buildings in Serbia through history, the regulations regarding design process of school buildings that influenced organizational schemes, regulations on thermal characteristics of the building and building thermal envelope elements. The advancements in construction technology and the development of systems, products, and materials were also considered. Finally, expert knowledge of the progress of architectural thought and styles in the design practice particular to our country was used as a vital criterion in establishing the typology. The basic matrix was defined by four time classes

- before 1945
- 1945—1970
- 1971—1990
- after 1991

and three classes by the school size (gross floor area):

- area smaller than 500m²
- area from 500 to 2000 m² and
- area larger than 2000 m²

resulting in the matrix with 12 building types.

1.1.3. Cluster analysis

The method of clustering, using the k-means algorithm in cluster analysis has been adopted as the main principle for distinguishing of defining characteristics. Clustering methods groups a set of objects into clusters so that objects in the same cluster are more similar to each other than objects in different clusters according to some defined criteria [14], or in other words clustering aims at finding smaller, more homogeneous groups from a large heterogeneous collection of items [15].

These similarities in the case of building stock assessment are represented by characteristics that influence building energy performance, defining the groups of buildings by their predefined characteristics. All buildings from the sample that belong to a certain type (size class) and period of construction (age class) were grouped according to chosen indicators: size, number of floors, compactness, and type of roof and façade wall predominant material. The number of indicators in cluster analysis is limited, so 5 parameters were chosen that are considered to describe the typical building in the best way. This practically means that within a period of construction and for a size type the maximum of five groups of buildings are defined. Out of the identified groups, the most typical is the one with highest representation (in %). If two groups have the same (or similar) representation than the other set of building characteristics should be considered also and a type and sub type should be defined. In this way, the description of typical buildings is rendered and serves as the model buildings (Table 1).

Table 1. Description of the model school buildings

Period	Analysis parameters	GFA < 500m ²	GFA 500-2000m ² type / subtype	GFA >2000m ² type / subtype
Before 1945	1.GFA 2.No. of floors 3.Compactness 4.Roof type 5.Facade wall material	235m ² GF Compact Pitched roof Brick	810m ² /1310m ² GF / GF+1 Compact/partially complex Pitched r. / pitched r. Brick / brick	2890m ² / 3185m ² GF+1/ GF+2 partially com./ complex Pitched r. / pitched r. Brick / brick
1945 – 1970	1.GFA 2.No. of floors 3.Compactness 4.Roof type 5.Facade wall material	145 m ² GF Compact Pitched roof Brick	1160 m ² GF+1 Compact Pitched roof Brick	3010 m ² GF+2 Complex Pitched roof Brick
1971 – 1990	1.GFA 2.No. of floors 3.Compactness 4.Roof type 5.Facade wall material	255 m ² GF Compact Pitched roof Brick	1610 m ² GF+1 Compact or complex Pitched roof Brick	2660 / 5045 m ² GF+1 / GF+2 Complex/ partially comp. Pitched roof Brick/concrete
After 1991	1.GFA 2.No. of floors 3.Compactness 4.Roof type 5.Facade wall material	230 m ² GF Compact or complex Pitched roof Clay block	995 m ² GF+1 Compact Pitched roof Clay block or brick	6200 m ² GF+2 Complex Combined roof Clay block or concrete

1.1.4. School buildings typology matrix

As it was mentioned before, the total number of school buildings in Serbia is 3890. Comparing that number to the number of surveyed buildings and to the distribution of number of buildings in the matrix (in %) it was concluded that for some types there are not enough representatives that will give statistical sample big enough for decision making and for the selection of real representatives. As the benchmark the representation




of 1.5% was adopted and types with smaller sample were deleted from the typology table (Table2).

Table 2. Distribution of schools by period of construction.

Period of construction (year)	Small schools (below 500 m2) %	Medium-sized schools (500-2000 m2) %	Large schools (above 2000 m2) %
before 1945	13.37	6.92	5.58
1946 - 1970	15.30	10.33	12.39
1971 - 1990	7.76	6.32	9.51
after 1991	1.36	1.16	1.77
N/A	1.23	0.62	0.49

By thorough examination of the database, using a software that was developed exclusively for this purpose, school buildings were identified that best corresponded to the descriptions of model school buildings, and they became the real representatives of the model buildings (Table 3.).

Table 3. The typology matrix of the chosen representative buildings.

	1_SMALL <500 m ²	2_MEDIUM 500-2000 m ²	3_LARGE >2000 m ²
A <1945			
B 1946-1970			
C 1971-1990			
D >1991			

An example of further calculations done for each of 13 identified types are given in figure below (Figure 1). Energy class based on energy need for heating [16, 17] is determined for designed state (0), state after most frequent interventions, like window replacement in the last decade (I), and three levels of improvements (1,2,3). By multiplying specific energy need with the data about distribution of each type in the building stock, data about estimated current consumption and savings after improvement scenarios are calculated.

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