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Indoor air quality in elderly homes in Serbia - Evidence-based design methodology

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***Abstract**: This study represents the first phase of research into the relationship between indoor air quality and the architectural and thermotechnical characteristics of buildings. The focus is on specific categories of users such as the elderly. The research methodology based on the scientific method is presented, which examines the condition of real objects on the territory of the Republic of Serbia. The aim is to provide a structured methodology for establishing the link between architecture, mechanical systems and indoor air quality, on evidence-based design principles, in order to propose guidelines for future interventions in the construction or adaptation of facilities for the elderly. Second objective of the study is to point to the relevance of contextualized interventions according to the target user groups and reinforce application of scientific evidence in contemporary building design. Namely, tailor-made solutions would be necessary in the future, and consideration towards different*

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user needs should be framed and structured to meaningfully operationalize the design.

***Keywords**: indoor air quality, architecture, elderly, evidence-based design*

Kvalitet unutrašnjeg vazduha u domovima za stare u Srbiji - metodologija projektovanja zasnovana na dokazima

***Apstrakt**: Ova studija predstavlja prvu fazu istraživanja odnosa između kvaliteta vazduha u zatvorenom prostoru i arhitektonskih I termomehaničkih karakteristika zgrada. Fokus je na određenim kategorijama korisnika kao što su starije osobe. Prikazana je metodologija istraživanja zasnovana na naučnoj metodi, kojom se ispituje stanje realnih objekata na teritoriji Republike Srbije. Cilj je da se obezbedi struktuirana metodologija za uspostavljanje veze između arhitekture, mehaničkih sistema i kvaliteta vazduha u zatvorenom prostoru, na principima projektovanja zasnovanim na dokazima, kako bi se predložile smernice za buduće intervencije u izgradnji ili adaptaciji objekata za starije osobe. Drugi cilj studije je da ukaže na relevantnost kontekstualizovanih intervencija u skladu sa ciljanim grupama korisnika i podstakne primenu naučnih dokaza u savremenom projektovanju zgrada. Naime, u budućnosti će biti neophodna rešenja po meri korisnika, a razmatranje različitih potreba korisnika treba biti organizovano i strukturirano kako bi se dizajn smisleno sproveo.*

***Ključne reči**: kvalitet unutrašnjeg vazduha, arhitektura, starije osobe, dizajn zasnovan na dokazima*

1. Introduction

Previous research in the field of indoor air quality shows the complexity of the field and points research in different directions (Chau, et.al., 2008; Tu, et al., 2019; Almeida-Silva, et al., 2014). Recent studies, which have shown that outdoor air plays a major role in indoor air quality, are reviewing heating, cooling and ventilation systems in different physical contexts (Chau, et.al., 2008). Another insufficiently researched direction is the physical structure of buildings and its connection with the quality of indoor air (Mendes et al., 2015). This has become extremely important with specific user groups, such as the elderly (Mendes et al., 2013). It is clear that examining the interaction of the mentioned parameters is a complex task, where software tools play a significant role in

order to simulate the scenarios needed to analyze all the parameters within researched physical context (Sung & Hsiao, 2021).

The study aims to examine the connection between indoor air quality and building architecture and outdoor air characteristics through a series of scenarios created through simulation. The subject of the study is a real facility - a home for the elderly residents. It is located in Belgrade and its primary activity is the medical care of users. The simulation involves modeling an object with all its real characteristics as well as the characteristics of the context in which the object is located, and was conducted in the IES VE software package. The aim of this paper is to answer the following research question which is the result of the analysis of the presented literature:

To what extent do the interaction of architecture and thermomechanical systems of the building affect the quality of indoor air?

2. Background

A significant number of studies deal with indoor air quality, but the subject of this research is most often business facilities (Chau, et.al., 2008). Unlike business, homes for elderly and educational facilities are characterized by different dynamics of space use, where activities are less controlled and where user behavior is less predictable (Chau, et.al., 2008). Also, staying in one space lasts longer for the elderly, and the impact of the environment is much more significant compared to business or other facilities where the stay is in some way limited in time. Therefore, examining the impact of space elements is complex and there are several aspects that must be taken into account. Factors of the immediate physical environment that affect air quality are primarily ventilation systems (Tu, et al., 2019). A study conducted on 384 respondents (elderly people) who are users of a nursing home in Portugal, showed that this category of users spends 95% of their time indoors (Almeida-Silva, et al., 2014). The analysis of qualitative and quantitative data led to the conclusion that the ventilation system is not adequately optimized and that the rooms where users spend the most time (bedrooms and living rooms) have CO_2 concentrations that are more than acceptable. One of the arguments that the authors state is that mechanical ventilation is not sufficiently represented, which makes timely ventilation difficult.

In addition to factors from the immediate physical environment, air quality is also affected by individual user characteristics (Persily & Jonge, 2017). Recent studies show that physiological parameters related to a person's metabolism affect CO_2 emissions during respiration (Jacob Rodrigues, Postolache &

Cercas, 2020). Also, the amount and type of physical activity also affect the concentration of CO_2. Thus, two different people can contribute in different ways to the concentration of CO_2 and thus to the quality of indoor air (Matz et al., 2014). The presented study (Persily & Jonge, 2017) suggests monitoring user activity, as it was found that there are differences in CO_2 concentration between rooms where people are less active and rooms where users are more active. The study also suggests that future research should take into account the time frames of people's stay and activities in a particular area. In addition to the users themselves, other living organisms indoors have also been studied. The role of plants in air purification is the subject of research that has so far shown a positive impact of these organisms on indoor air quality, especially in reducing the presence of TVOCs including formaldehyde, benzene, toluene, etc. (Pegas et al., 2012; Wang et al., 2014; Dela Cruz et al., 2014, Tsai, 2018). A recent study of houseplants published interesting results of a study that compared two groups of elderly people (Chen, et. Al., 2020). One group consisted of users who do not have a plant in their life, and the other group consisted of those who did. The particular matter less than or equal to 2.5 μm in diameter (PM2.5) and total volatile compounds (TVOCs) have been linked to heart rate and blood pressure. The results of the study show that the problems with these health conditions are more prevalent in areas where there are no houseplants.

In addition to the internal influences on air quality, the proven and logical influence of outdoor air on indoor quality is an important parameter of any research in this area. Considering the different ways to manage thermal comfort and room ventilation, (Chau, et.al., 2008) identified the need to provide control of outdoor air entry, which greatly affects indoor air quality. Ventilation through the window, without a purifier is not enough. By installing adequate systems that perform air purification, it is possible to achieve satisfactory health conditions that directly reflect on the economic aspect of this problem. Interestingly, the mentioned study suggests that a much greater benefit is achieved by using a purifier, rather than by relocating accommodation to locations where outdoor air pollution is less. (Mendes et al., 2015) also point to the connection between external and internal air quality, pointing out that poor indoor air quality causes cardiovascular and pulmonary diseases, which greatly affect the quality of life (Wilker at. Al., 2011). Protocols that provide guidelines for cleaning, ventilation, and heating have been proposed as a necessary measure to preserve user health and comfort.

Given the gap that exists between architectural design and the collection and identification of evidence that would support that design, this paper aims to propose a methodology that would ensure the collection of valid evidence and

include it in the design process. In this way, the mentioned gap would be reduced to a certain extent and a sustainable approach for further action in this area would be created. The topic of indoor air quality is closely related to architecture, but the share of mechanical design is equally important, which, in addition to the physical space, focuses on installations whose role in air quality is essential. Therefore, the goal of this research is multidisciplinary and complex. The research question that present the basis of presented research is:

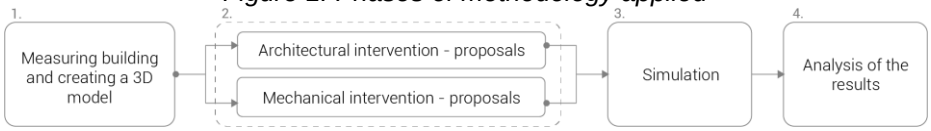
How can evidence-based methodology contribute to the architectural and mechanical design process with the aim of achieving higher air quality in residences for elderly?

3. Methodology

3.1. Evidence-based design

The approach to answering research questions is based on an evidence-based design methodology that points to the importance of using evidence from literature and practice to inform design. In other words, scientific method and experimental techniques play a key role in the design process. The methodology for applying the evidence-based approach to assessing the state and proposing interventions concerning indoor air quality consists of several phases (Figure 1).

Figure 1. Phases of methodology applied



3.2. Case Study - BG Dom 56 residency for elderly

The facility selected as the case study is a private residence for the elderly, BG Dom 56, located in Belgrade, Jovana Popovića 7. (Figure 2). The residence is intended for users who need medical care, so there is staff trained to provide the necessary medical care. It consists of two buildings, both of which are

residential. The larger building also houses service rooms for food preparation and storage, storage of medical supplies and offices. The building is located on a plot where there is a green area intended for activities of tenants. The obtained project documentation provides a detailed insight into the layout of the premises, dimensions, projected electrical installations and openings in the building. There is no central heating, cooling and ventilation system. Heating is done centrally, through the city heating plant. Cooling is done by opening windows and deploying air conditioners, while ventilation is done exclusively by opening windows. The building is located in the urban zone of Belgrade.

Figure 2. Photographs of the case study object - BG Dom 56 residency for elderly, located in Belgrade, Jovana Popovića 7

3.3. Stages of creating and testing the scenarios

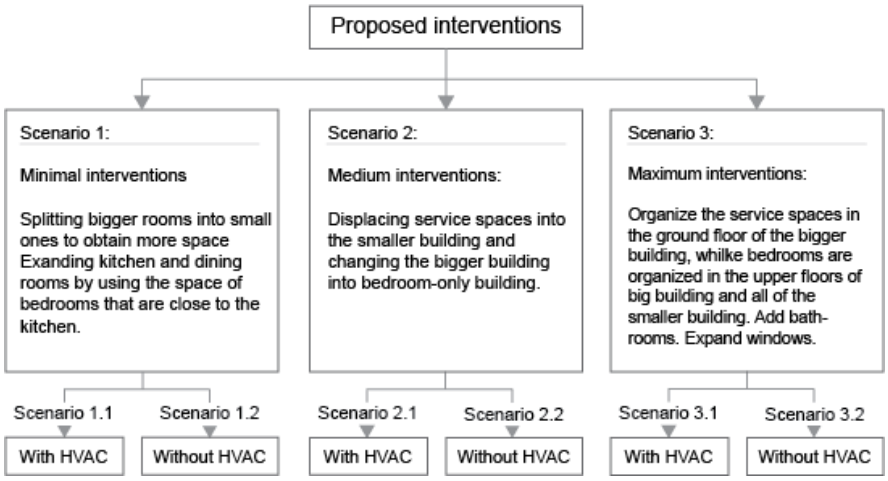
The first phase involves going to the field, where the researchers surveyed the building and got acquainted with the technical documentation of the building. The activities carried out in the field are listed in Table 1. The aim of data collection is to gain insight into the current situation and to establish the basis on which further proposed interventions can be simulated. Therefore, the first phase would be to make a model of a real object with the accompanying characteristics of the location, HVAC systems, meteorological conditions, etc.

Table 1. The structure of surveyed enterprises by number of employees

Activity	Type of the data
Insight into project documentation. Assurance that the documentation is complete and that the necessary information for the simulation can be obtained.	Project documents
Photographing the object from the outside and mapping details that are important for the simulation, such as small cracks in the façade, finishing, etc.	Photos
Interviewing employees about how the facility is used by tenants	Survey
Collection of qualitative data on the chronology of daily events, demographics of home users, service provided, staff activities, etc.	Survey

The second phase of the methodology is based on the identification of intervention scenarios that aim to examine the effects of different interventions and their impact on indoor air quality (Figure 3). Interventions in the field of architecture and mechanical engineering would be proposed. Namely, the aim is to develop a model of the modified architecture of the building where the changes would relate to 1) the structure of the walls (simple interventions, but suggested in the literature - moving the sleeping area away from the kitchen, etc.); 2) doors and windows; 3) the facade of the building. Furthermore, simulation of different HVAC systems would be conducted, where, based on the literature studies, different HVAC systems would be deployed. This phase of methodology is the most important one, as it depicts the main aspects of the contribution. Namely, proposed interventions will generate scenarios that would be simulated and, within simulation, compared. All scenarios are considered at early design stage level, assuming that radical changes would be possible. This paper does not include cost estimations, which are planned as a future work. All scenarios also include change of the facade, while the changes in wall arrangement, functional organization and windows, differ between them.

Figure 3. Scenarios of proposed changes



The third phase would consist of the simulation conducted in the IES-VE software. Multiple scenarios would be performed, which include multiple 3D models of the residency home according to the proposed architectural interventions. Furthermore, different HVAC systems would be implemented and the combinations between interventions would be observed. Comparisons between scenarios would be the main focus of the simulation. Finally, the fourth phase would be the analysis of the results where the multiple scenario outcomes would be compared.

3. Discussion and Conclusion

In order to answer the research question, we formulated a methodology that is based on evidence-based design principles. Through the creation of interventions that are supported by the literature, the goal is to create a set of evidence that would indicate the possibilities of optimizing the space in order to achieve better health conditions in the home for the elderly. From the presentation of the methodology, it is clear that there are many challenges when it comes to the proposed interventions. The task of optimizing a specific space, especially when dealing with special purpose spaces, requires a very structured methodology. Evidence-based design allows scientific access and testing of multiple solutions through simulations. However, at this stage of the

project, it is unknown to what extent the methodology will provide when it comes to optimization. Therefore, a model has been created that is adaptable and by crossing several elements from different scenarios we can see how additional iterations can contribute to the solution. Sustainable methodology based on the evidence-based design principle provides the ability to generalize the method and its application and other contexts. Future work includes testing the methodology on the mentioned object through the development of a simulation. Also, future work will include additional facilities such as kindergarten and primary school. In this way, the adaptability of the methodology will be examined, as well as possible contributions in the field. The limitations of this study are related to the early stages of methodology development where potential downsides are not visible, which will be addressed in further work.

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