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SYNERGY OF ARCHITECTURE & CIVIL ENGINEERING
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International Conference

Synergy of Architecture & Civil Engineering

Niš (SERBIA) - Science & Technology Park Niš - September 14-15, 2023

PREFACE

The primary goal of the SINARG 2023 conference is to present contemporary achievements in the scientific and practical aspects of architecture and civil engineering. The organizers of the conference aimed to facilitate the participation of both national and international professionals in theoretical and experimental research related to the processes of design, project management, construction, and building maintenance within the construction industry.

Simultaneously, this scientific conference serves as a platform for exchanging experiences and information regarding innovations and advancements in planning, design, new materials, and construction and reconstruction technologies within the fields of architecture and civil engineering.

Therefore, this conference should serve as a forum where experts from civil engineering, architecture, and other related fields have the opportunity to present the results of their research. In that context, conference topics have been carefully selected to provide focus on current issues in the field and encourage productive discussion bringing fresh and original insights and concepts to the forefront.

More than 180 paper proposals have been submitted to the conference. A single-blind review process was used to assess the full papers. The reviewers are esteemed scientists holding PhD degrees in the same field as the paper's topic. There are more than 70 reviewers from ten countries who have significantly contributed to the scientific quality of the conference, and their names are printed in the proceedings.

A total of 142 full papers have been accepted for publication. Some of the papers have been selected for publication in our journals, with nineteen papers in Facta Universitatis: Architecture and Civil Engineering and nine in the Journal of the Faculty of Civil Engineering and Architecture. The conference proceedings consist of 114 papers divided into two volumes.

The total number of authors and co-authors accepted for publishing at SINARG 2023 exceeds 320. Out of this number, more than 80 authors come from abroad, representing 19 countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Germany, Greece, Hungary, India, Indonesia, Netherlands, North Macedonia, Montenegro, Oman, Poland, Romania, Serbia, Slovakia, Turkey, United Kingdom).

The editors express their gratitude to all the authors for their participation and to the reviewers for their valuable comments, which have contributed to the improvement of the original manuscripts and have enhanced the overall quality of the conference..

Niš, September 2023 *Editors*

CONTENTS

EXTENDING THE LIFE OF RESIDENTIAL BUILDINGS THROUGH ADAPTATION: A CASE STUDY OF NIŠ, SERBIA

Branislava Stoiljković[1], Hristina Krstić[2], Nataša Petković[3], Vladana Petrović[4]

Abstract

Circular economy tends to extend the life of products, maximize reuse and recycling, and return all waste material to the production. Since the building sector is one of the main consumers of natural resources and energy, considerable polluters, and substantial producers of waste, it is one of the priority sectors for the application of circular models. Due to the irreplaceable role of architects in the process of creating architectural structures, they are recognized as important bearers of change in the green transition, and it has become clear that circular principles should be incorporated into architectural design as well. Adaptability of buildings is considered one of the most important principles of circular economy in the building sector and one of the key aspects in making housing more sustainable. Through an analysis of selected residential adaptation projects in Niš, Serbia, this paper gives an overview of some possible approaches to housing adaptations, as a model for extending the life of buildings.

Key words: adaptability, housing adaptation, circular economy, architectural design, case study

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1. INTRODUCTION

Unlike the linear economy, which is based on the "take-make-dispose" model, the circular economy aims to extend the life of products, maximize reuse and recycling, and return all waste material to the production process. While the linear model implies the persistent consumption of raw materials and energy, processing and use, and finally the continuous production of waste, circular model achieves efficient use of resources, reduction of environmental pollution, financial savings and creation of new business opportunities. The building sector, as one of the main consumers of natural resources and energy, considerable polluters, and substantial producers of waste [1-3], is one of the priority sectors for the application of circular economy business models, due to the potential for improving the economic system in relation to economic and environmental impact. Since architects are important participants in the process of designing and building structures, it is clear that circular principles should be incorporated into architectural design as well [4]. Architect designers, due to their irreplaceable role in the creation of architecture structures, are recognized as important agents of change in the green transition, which, among other things, implies new approaches at the building design scale. One can recognize several important potentials in this area: application of circular design, use of environmentally friendly materials for construction, recycling of demolition and construction waste, etc.

Circular design is one of the key approaches to implementing circular economy in the built environment. The way buildings are designed affects the way they are used, the impact they have on their surroundings and how long they remain fit for purpose. Therefore, the application of circular design strategies for buildings is required, with a special focus on extending the life of buildings [5]. Practices in the design sector that can be applied in the transition to the circular economy include, among other principles, design for flexibility, which implies the use of underutilized space, expansion capacity, demountable partitions and so on [6]. The Ministry of Environmental Protection of the Republic of Serbia in the Roadmap for CE in Serbia [7] proposes a circular model of product life extension for application in the built environment sector; it implies repairs, modifications, or redesign of an existing product, allowing the product to be in use longer, thereby simultaneously extending the life cycle of products and materials.

Adaptability of buildings is considered one of the most important principles of circular economy in the building sector [8]. It prevents premature building demolition by developing a new design culture. Adaptability is one of the key aspects in making housing more sustainable. The application of adaptive design has the potential to reduce environmental impact, as such buildings can be adapted to new needs by reconfiguration, instead of demolition and rebuilding. This kind of design anticipates changes in requirements and enables transformations of the building for better use, reuse, or new ways of using. This means that such buildings are more durable, and longevity can be regarded as an essential condition for environmentally sustainable housing [9, 10].

In today's time of rapid and frequent changes in society, the reversibility and adaptability of residential buildings are becoming one of the main priorities for architects. The personalization of housing has become widespread, and the needs for individualization due to lifestyle changes have recently increased. The periods between changes of purpose, renovation or reconstruction are getting shorter, so it

is increasingly necessary for residential buildings to meet different demands and needs during their lifetime. Architects need to consider several aspects, including functional, structural and aesthetic adaptability. The purpose of this paper is to give an overview of some possible approaches to housing adaptations, taking into account all the above-mentioned aspects.

2. METHODOLOGY

Circular building approach has gained considerable attention during the past decade and there is an increasing number of scientific researches dealing with it. It is particularly justified to focus on residential construction, bearing in mind that it represents a significant share in the consumption of material resources, as well as the potential for achieving material efficiency. Moreover, housing adaptation projects, as one of the principles of life-cycle extension of buildings, deserve special attention.

The application of circular design in Serbia is still at a very low level. However, residential building adaptation projects, such as are often realized in Serbia, are examples of projects that deal with extending the life of buildings. Therefore, these projects are examples of good practice in the application of circular economy principles in architectural design and are extremely illustrative for a better understanding of the level (intentional or accidental) of the application of circular models.

In order to analyze and present possible different approaches to the adaptation of residential buildings, the authors conducted a case study, which is an appropriate research design to gain concrete, contextual, in-depth knowledge about a specific real-world subject, and presented selected adaptation projects of residential buildings in Niš, Serbia. The selection of projects was made in such a way that different types of adaptations, different sizes of buildings and different degrees of modification and renovation were represented (alterations of the floor plan, replacement and upgrading of individual components, adding an extension, partial demolitions, remodeling of the facade, energy refurbishment, etc.), bearing in mind that buildings have a residential purpose.

Table 1. Overview of the selected housing adaptation projects

No		Architectural studio	Year of construction	Number of floors	Number of units
1	original	/	1935	B+G	1
	adaptation	Teking	2023	B+G+2	1
2	original	/	1938	B+G	1
	adaptation	Alterno	2023	B+G+1	2
3	original	/	1969	G+4	4
	adaptation	Polyarch	2022	G+4	4
4	original	/	1978	G+2	3
	adaptation	Kubik	2021	B+G+2	9

The main criterion for the selection of projects for the case study was to represent both family and multi-family housing buildings, with both keeping the same number of units and increasing the number of units after adaptation, which brings us to the

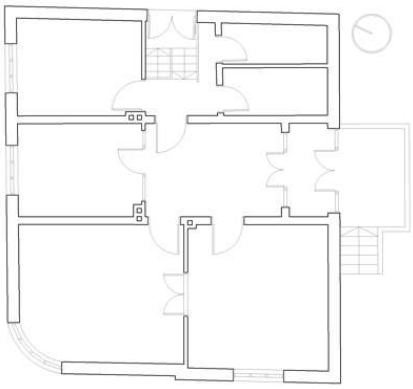
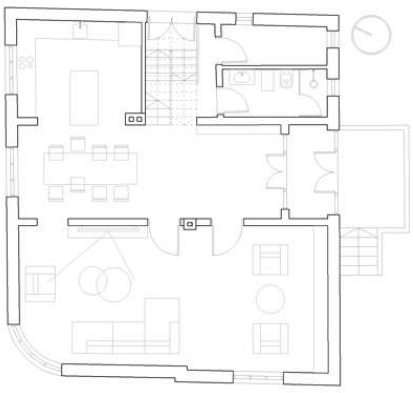
four analyzed projects. The presented adaptations include: adaptation and extension of a family house for the new needs of the old owners, adaptation and extension of a family house with one unit into a building with two residential units, adaptation of a multi-family residential building with the addition of previously unused space and adaptation of a multi-family residential building with three units into a building with nine units. An overview of the selected housing adaptation projects is given in table 1.

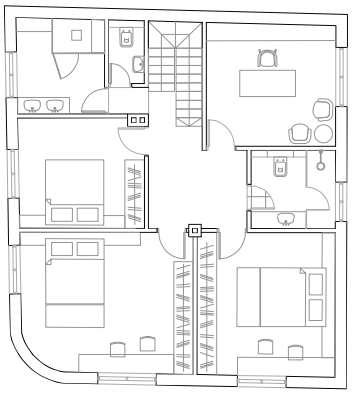
3. RESULTS

3.1. **Project no. 1**

The project included the adaptation (with an extension) of a pre-war urban villa for the new needs of the same users in terms of increasing the living space, modernizing the functional characteristics of the unit, and creating a modern building in a visual sense. The existing residential building was built on a traditional masonry construction system with a sloping roof. The facade walls of the existing building were completely preserved, as well as the arrangement of the openings on the facades, while part of the interior walls was demolished in order to connect the rooms and achieve a better functional configuration. The roof structure was removed. An open plan living room was created on the ground floor. The existing floor covering was retained. The structure of the extended part of the building is prefabricated from GLT elements. The facade and partition panels are filled with mineral wool and closed with gypsum-fiber boards, which is a base for further processing on the interior and facade side. The roof of the newly designed part is flat. The plumbing system was improved. The extension is in formal and aesthetic contrast with the existing volume of the ground floor. The use of GLT elements is not very common in the design of residential buildings in Serbia and in this case it was encouraged by the close cooperation between architects and manufacturers. The material left over from the demolition of the walls and roof structure is not reused but is taken to the city landfill. (Table 2)

Table 2. Graphic overview of the adaptation project No 1 (Source: Teking, Niš)

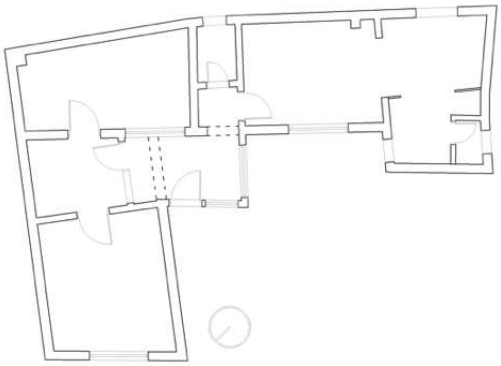
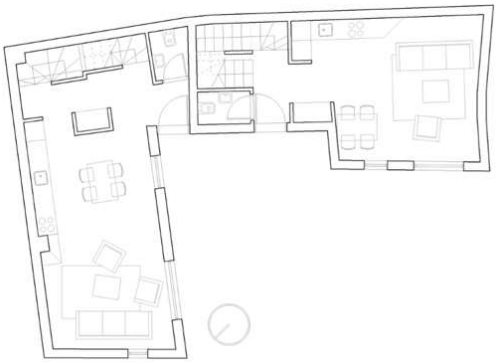
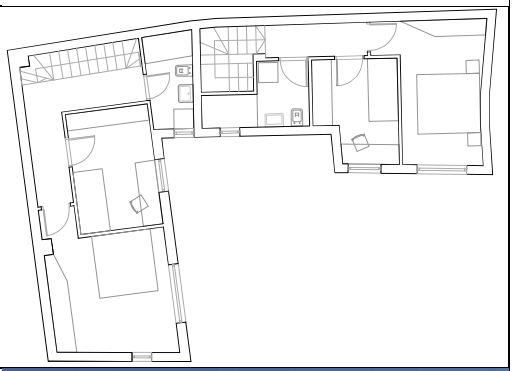
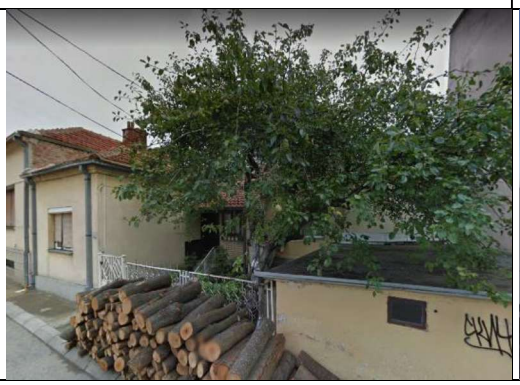
	original	*adaptation*
Ground floor plan		

First floor plan	*X*	
3D view		

3.2. **Project no. 2**

The existing building was an old single-family house, built on a traditional masonry construction system with a sloping roof. The new clients, at the same time the architects of this project, planned the construction of two residential units for their own needs through the adaptation and extension. The existing facade walls were kept, while the interior walls were mostly removed (except in the part between the two units) to create an open plan ground floor. The arrangement of the facade openings is adapted to new functional and aesthetic needs. Due to dilapidation, it was necessary to demolish the floor structures above the basement and ground floor and build new ones. The first floor was added over the entire surface of the ground floor, in a brick masonry system. Due to the disrepair and poor quality of the originally installed materials, they were not reused after demolition. The roof above the added floor is flat. The existing facade walls (as well as the new ones) were completely thermally insulated during the renovation. The existing plumbing system was completely replaced with new one due to its poor condition. In terms of aesthetics, the renovated building has a completely different, modern expression. The rubble that remained from the demolition of the walls, floor and roof structure was transported to the city landfill. (Table 3)

Table 3. Graphic overview of the adaptation project No 2 (Source: Alterno, Niš)

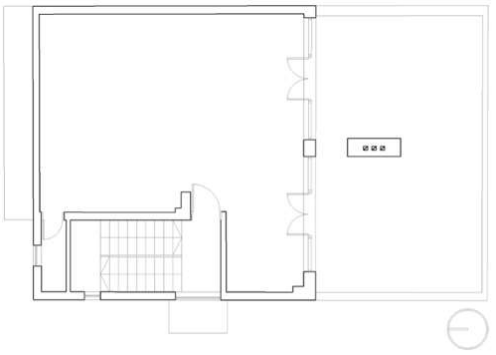
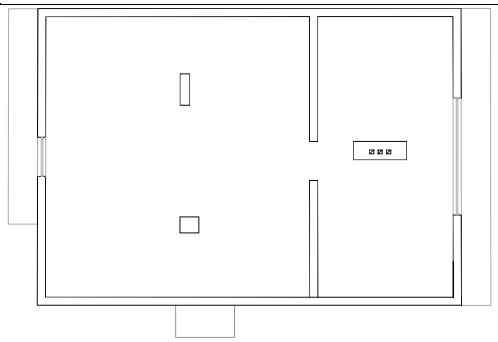
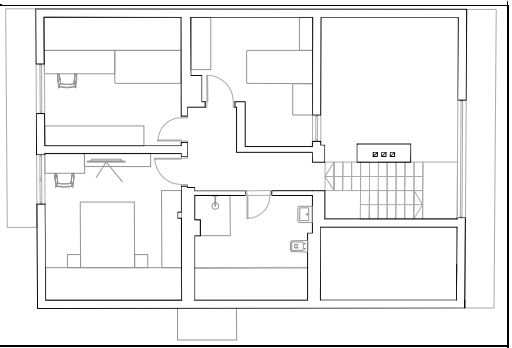
	original	*adaptation*
Ground floor plan		
First floor plan	*X*	
3D view		

3.3. Project no. 3

This is an adaptation project of a multi-story residential building with four identical apartments on four floors and attic space. The new owners of the building wanted to renovate and modernize the residential units, so that they could sell them more profitably on the real estate market. The project planned to keep the same number of units, and the apartment on the fourth floor became a duplex and the previously unused space in the attic was added to it. The structure of the existing building was made of masonry with horizontal and vertical reinforced bands. The facade and load-bearing internal walls were mainly retained, while the arrangement of the facade openings remained mostly the same. Partition walls were partially demolished for better use of space, obtaining more bedrooms, creating different unit layouts and, in general, better, and more functional configuration. Some rooms, due to their neutrality in terms of shape, dimensions and position within the unit, were easily given another purpose, without the need for demolition and rebuilding (for example:

the living room "moves" into a space with a southern orientation and the bedroom "moves" closer to the second bedroom). Wood flooring was replaced with laminate flooring. The position of the bathroom plumbing systems remained the same, while new plumbing systems were made for the kitchens, in accordance with the new organizational solution. The building has been visually modernized and significantly improved in terms of energy efficiency. All rubble left after the adaptation of the building was transported to the city landfill. (Table 4)

Table 4. Graphic overview of the adaptation project No 3 (Source: Polyarch, Niš)

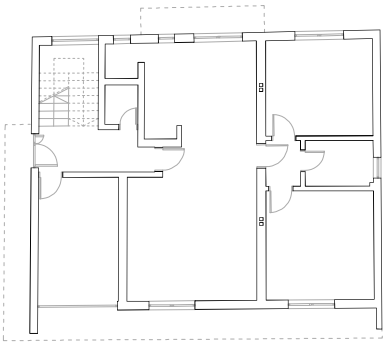
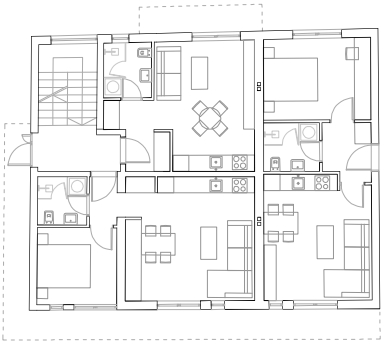
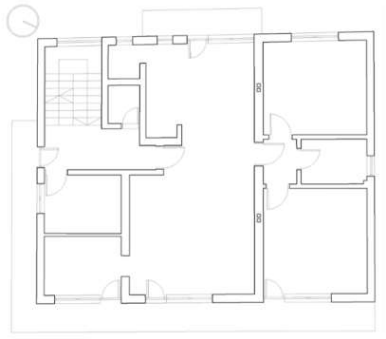
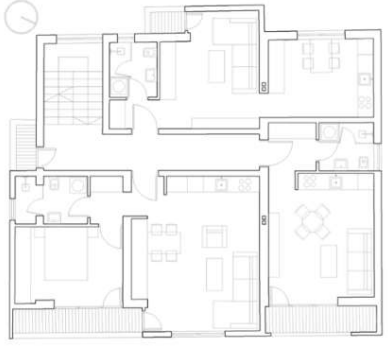
	original	*adaptation*
Third floor plan		
Attic plan		
3D view		

3.4. **Project no. 4**

The existing building was initially intended for an extended family consisting of three households, and was built with three identical residential units, one on each floor. After two households moved out, the owners decided to renovate the building to create more small units that can later be sold more easily on the real estate

market. The architects planned three apartments per floor, a total of nine, as well as the extension of the basement floor, which would contain the storage rooms. The structure of the existing building was masonry, and it was completely preserved, while some partition walls were demolished in order to achieve a more optimal unit layout. The position of the facade openings was partially retained. As it was necessary to strengthen the floor structure, the existing floor finish was removed (and completely replaced) and a reinforced screed was poured over the existing slab. Since the existing wooden roof structure was in bad condition, the project planned to replace it. Due to the multiplication of the number of units, it was necessary to install new plumbing systems for bathrooms and kitchens in addition to the existing ones. The facades have been refined, improved and modernized, and the entire building is thermally insulated. The rubble that remained from the demolition of the walls, floor and roof structure was transported to the city landfill and old materials were not reused. (Table 5)

Table 5. Graphic overview of the adaptation project No 4 (Source: Kubik, Niš)

	original	*adaptation*
Ground floor plan		
Second floor plan		
3D view		

4. DISCUSSION

The analysys of selected housing adaptation projects showed several directions of architects' actions, grouped into four categories: functional organization of space, building structure, mechanical, electrical and plumbing (MEP) system and aesthetics of building.

When talking about the functional organization of residential units, it was noticable that architects predominantly strive to create an open plan living space, regardless of the functional configuration of the existing unit, which often causes the demolition of existing walls. However, if the rooms in the existing unit are neutral (in terms of dimensions, shape, position), they get a new purpose in a newly designed solution, more appropriate to modern housing requirements, without demolishing and/or moving walls. On the other hand, the considerable space fragmentation of the existing units, although inadequate for the application of the open plan principle in larger apartments, favors the division of the initial unit into several smaller ones, which is to a certain extent in line with the current demand on the real estate market. Adding previously unused spaces to the apartment can improve its functional organization and comfort.

The residential buildings selected for the case study were fully built in the traditional masonry system, with or without horizontal and vertical reinforced bands. It was observed that non-bearing, and very often load-bearing brick walls cause a significant obstacle to architects in creating a modern, open plan living space, so they often decide to demolish the existing walls. When demolishing parts of the load-bearing walls, the necessary special reinforcements of the building structure were applied. Although the need to renovate the building is mainly for functional reasons, it has also been used to strengthen or replace certain elements of the structure, which additionally affects the extension of the life of the building. Unfortunately, the reuse of the material left over from the demolition of the walls (as well as the roof structure, floor and wall coverings) was not recorded in the selected projects and all construction waste was transported to the city landfill.

During the renovation of the residential buildings, the architects also retrofitted the existing MEP systems. The reason for this is twofold – the creation of new, different functional configurations of units and the need to improve and renew the existing systems. In any case, this type of renovation contributes to extending the life of the buildings, which is in line with the principles of circular economy.

Adaptations of the buildings included, to a greater or lesser extent, the remodeling of the facades, depending on the architect's idea, the client's requirements, and the available budget. The work of the architects in this segment was related to the aesthetic modernization of the external appearance of the building, but also to the energy refurbishment of the facades, which ultimately contributes to energy savings and is in accordance with circular economy principles. Moreover, the replacement of windows and balcony doors contributes to a visual-aesthetic improvement, as well as an increase in energy efficiency.

5. CONCLUSION

The analysis of selected examples allowed the authors to draw several key lessons regarding residential adaptation projects. They relate to functional, structural and aesthetic adaptability.

The functioning of a modern household requires a modern approach to solving unit plan configuration. The considerable division of living space usually does not correspond to modern housing needs, as well as the open plan design principle. Therefore, demolishing partition walls and connecting rooms is a common choice. However, as there is still considerable demand for smaller apartments in the real estate market, dividing existing units into several smaller ones is also a common solution. In this case, it is most often necessary to additionally partition the units, as well as introduce new MEP systems. Furthermore, designing apartments with identical plan configurations on all floors in today's time of pronounced pluralism in society proves to be unsuitable. When changing the users of the residential unit, but also when the needs of the existing users change over time, the flexibility of the space is obviously a very desirable characteristic, because it enables modifiability and different ways of using the space. Giving unused or underused spaces a new (residential) purpose can contribute to realizing the full potential of space which is in line with the principles of the circular economy.

It was observed that the lower the quality of the existing structure, the greater the extent of demolition. What is particularly worrying is the fact that the analyzed projects did not consider the reuse of the material left over from the demolition (bricks from demolished walls, elements of the removed wooden roof structure, floor-, wall- and ceiling coverings…). As expected, all construction waste was taken to city landfills where it was mixed with other waste, since there is no landfill for construction waste in Serbia. This is exactly the aspect that needs to be significantly improved in future renovations of residential buildings.

When the building has a certain historical value, architects often decide to completely keep the existing facades, and to leave a mark on the extension. Otherwise, the architect's ideas about the aesthetic modernization of the facades were accepted in accordance with the budget.

The concept of adaptive housing has always been associated with the building's ability to respond to changing demand. It is necessary that housing can adapt to changing market conditions and different users' requirements. From the perspestive of extending the life span of residential buildings, they should be designed and constructed to easily adjust to the evolving lifestyle of their residents or to different lifestyles of new ones. This could be done either by facilitating the continuation of the intended use or through possible future changes in use.

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