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**Research paper**

# Research by design: functional flexibility of a residential skyscraper located in Warsaw

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**Abstract:** The paper is devoted to the description of the methodology and research by design carried out to identify solutions enhancing the functional flexibility of a high-rise building located in Warsaw at. Grzybowska Street. The work presents the theoretical background as well as the conducted research and methodology. The scope of solutions related to functional flexibility concerned the interchangeability of service functions in the podium part of the building, changes in the use of the parking lot, and the provision of the means of changes in the arrangement of types and variants of types of apartments on the apartments levels. The investigation was carried out in the pre-design and design phases. Objectives and criteria of solutions were defined, and research works were carried out through iterations and checking in terms of the cost-effectiveness . The adopted solutions consist in designing the optimal hard portion of the building – the core, the structural system, the arrangement of zones and installation rooms, and the use of structural and spatial over-designed systems. An optimal facade module has been developed. The research aims to introduce the design practice to the issue of flexibility, which is nowadays important for economic and environmental reasons.

**Keywords:** adaptability, flexibility, housing, high-rise, skyscraper, Warsaw

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# 1. Introduction

## 1.1. The subject and the goal of the paper

Flexibility of buildings is generally defined as the potential of space to accommodate to functional changes of users, including social, sustainability, and economic aspects.

Its advanced implementation, based on a mature palette of design strategies, dates from the mid-twentieth century. Generally declared as a design principle, it gained popularity with the flourishing of the modernist movement. As a feature of residential buildings, it has been clearly used since the 1960s, when it was associated with the possibilities of various arrangements of residential structures by users, as well as their participation in the construction process and the emerging idea of "open building". Among the key residential buildings, where it played a significant role in design solutions include Weissenhofsiedlung, Stuttgart (1927) by Mies van der Rohe, Diagoon Houses, Delft (1971) by Herman Hertzberger, the Genter Strasse scheme in Munich (1972) designed by Otto Steidle, Doris Thut, and Ralph Thut, Brandhöfchen scheme in Frankfurt (1995) designed by Rüdiger Kramm, housing scheme designed by Günther Domenig in Neufeldweg (1988) or Hellmutstrasse Housing in Zurich de-signed by ATP Architektur und Planung (1991). The theoretical background, of developing the problem of the flexibility of buildings, was presented in the works of H. Hertzberger [1] and N.J. Habraken [2, 3]. The problems of adaptive architecture and functional changes during use have been developed, among others by S. Brand [4]. It is worth noting that the flexibility of the building structure is also a derivative of the theory of "open form", formulated by the Polish architect O. Hansen [5], and the activities of the TeamX group, to which both O. Hansen and H. Hertzberger belonged). In the 21st century, an update of the theoretical assumptions concerning the flexibility of residential buildings was presented by T. Schneider and J. Till [6], who gave in their publication 160 examples of the implementation of buildings designed with the principles of flexibility as a design basis. Based on theoretical considerations, the most important of which are listed above, flexibility was understood by practitioners – designers broadly – primarily as the building's ability to absorb cultural, economic, and technological changes of the society [7–9]. Nowadays, in the third decade of the 21st century, the issue of flexibility of buildings understood as the susceptibility of a building to changes after construction has been updated due to the paradigm of environmental friendliness and economic aspects. In terms of the environmental role, flexibility is important in the framework of the circular economy [10], reducing the number of greenhouse gases in construction [11], primarily as a means of extending the Life Cycle of Buildings, construction waste, and the energy flexibility of building structures. In terms of economic aspects, there are currently visible efforts to reduce operating costs [12, 13], embrace the full life cycle of the building, and the readiness to increase the implementation costs in order to obtain significant savings in the future – e.g. system novelties, renovation or adaptation of buildings to other functions [14].

Flexibility became an intrinsic imperative for buildings for extending the life cycle design by encouraging reversibility and the easy maintenance of the technological choices that have been implemented [7]. The topic of the paper is related to design solutions enhancing the functional flexibility of high-rise residential buildings. The subject of the research in this area was a 165 m high building, designed in Warsaw at Grzybowska Str. in the location indicated in Fig. 1. Its total aboveground area, distributed over 47 floors, was 63,337 m$^2$, underground, distributed over 3 floors – 6,521 m$^2$. The usable living area was approximately 34,300 m$^2$ and was spread over 40 above-ground stories.

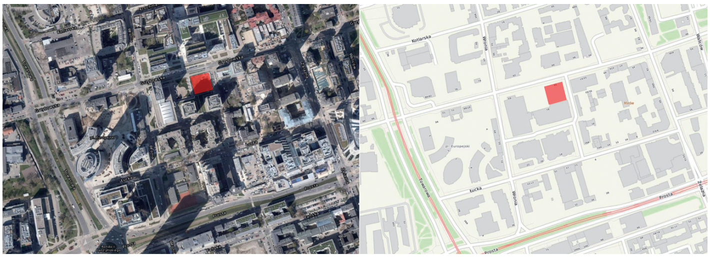

Fig. 1. Location of the building; source: Author's study

The works were carried out by the Kuryłowicz & Associates office in the field of architectural solutions and the WSP Polska office in the field of structural and installation solutions. The author of the text acted as a leading designer and manager of a set of design works. The aim of the paper is to describe the theoretical background, criteria, goals, and methodology as well as research conducted by design together with the results – final design solutions favoring flexibility. This is due to the observation that in professional practice it is evident that conventional design and implementation methods do not take into account the issues of adapting a building during its life cycle to changing aesthetic, functional, technical, and environmental requirements. The intention is to present the effects of the work that will draw attention to the problem and facilitate the introduction of the principle of the flexibility of high-rise residential buildings in future projects. The following ranges of building changes that occur during use and can be considered in terms of flexibility can be defined: function changes, capacity changes, and flow changes [15, 16]. Function changes are primarily spatial changes, capacity changes primarily involve changes in the construction and installation systems, changes in the flow – inside and outside the building, relating e.g. to energy flows and flows of users, including spatial changes and changes to installation systems and materials. This paper focuses primarily on the design aspects of designing a flexible building structure to allow for functional changes. The scope of possible changes included the number of flats, their configuration on the floors, and solutions for their internal layout. Flexibility in a given case was a design goal resulting from the investment uncertainty related to the market absorption for individual types and sizes of apartments. It was decided that the flexible building during construction of which commercialization will take place should be designed, and the number of pieces of individual types of premises at the start of construction may not be fully determined. As the orders and sales of various types of apartments would be progressed, they were to be successively implemented in the building structure, until it was finally filled in various configurations of apartments on the floors.

The strategy defined in this way assumed at the starting point to design the building in such an approach as to eliminate structural changes within the scope of functional flexibility and to minimize changes in the installation and service systems of the facility while introducing different apartment configurations to the constructed structure of the building.

## 1.2. Theoretical issues of flexibility of residential buildings

The usefulness of buildings is often limited by the insufficient possibility of introducing changes during their use or the limited possibility of transforming the building into new functions after the use of the primary function is exhausted. As the research of E.S. Slaughter [15] shows, the flexibility of a building – anticipating changes at the design stage and introducing the possibility of building adaptability to changes during implementation results several times compared to the costs of such introduction in implementation savings during the reconstruction of buildings. The flexibility of residential buildings can be analyzed on several levels: flexibility of apartments – from the possibility of their adaptation in terms of changes in equipment, furniture, material solutions to interior divisions, and the flexibility of the building structure, allowing for changes in the arrangement, number and size of apartments, and installation service. In housing development, there is a correlation between the frequency of changes, their scale, and the form of ownership. Changes in the level of equipment of the apartment are frequent, compared to other types of buildings, and are much more frequent than changes related to the size of the apartments or the number of apartments in the building. However, while changes to the structure of a residential building in the case of cooperative buildings or condominiums are rare, changes in the structure of residential buildings with apartments offered for rent are more frequent. In the case of buildings with apartments for rent, such changes reflect the current demand for apartments of an appropriate size and standard, hence, especially in their case, the flexibility feature is favorable for the subsequent management of the building. User studies provided by Dhar et al. [17] indicate that the most common causes of changes at all levels in residential buildings are: accommodation of a larger number of inhabitants, changes in functions, changes in the family structure, changes of use, changes in the ownership of apartments and buildings, renovation and renovation, modernization and introduction of new technologies. De Paris [18] gives the motives for applying flexibility more broadly – they are justified by the obsolescence of a building (when it no longer fits the current social dynamics), the economy of resources, sustainability, well-being, rapid and constant cultural changes, scarcity of new land, and personalization. Recognition of the hierarchy of change levels and their potential frequency of introduction may stimulate designers and decision-makers to consider the proper solutions to building flexibility [16].

The assumption behind the design of a functionally flexible building was to design the structure and systems of the building in such a way that the introduced changes did not affect the entire facility, and their future costs were as low as possible. Based on the literature [7–9, 15] investigations indicate the design scopes that are the means of introducing flexibility and the resulting strategies, methods, and procedures.

**Design scopes for introducing flexibility:**

– The main spatial parameters of the building.

- Links and spatial and functional relations between building systems: structure, services, internal and external partitions.
- Substitution and interchangeability of element groups or elements.
- Scenarios for future phased system expansion.
- Access to systems and ease of disassembly, replacement, and expansion of their components.
- Variation of future use options.
- Durability of fixed, non-replaceable building systems.
- Cost control of introducing solutions favoring flexibility.

Strategies, methods and design procedures:

- Limiting the interdependence between building systems, separating systems in terms of physical, spatial, and functional connections.
- Provision of access to installations, replacement routes, and introduction of replacement elements of central installations.
- Design of grouped areas for major components of plumbing systems and connections.
- Grouping of systems into zones to facilitate conversion or replacement without shutting down the entire system.
- Designing spatial allowances: e.g. for introducing other, additional devices, space reserves in shafts.
- Designing media reserves: reserves for an alternative function.
- Designing construction allowances.
- Designing regular, compact projections, with a flexible height of stories, proper arrangement of the shafts.
- Design of a column structure with larger spans.
- Basing solutions on a spatial module adapted to changes in future use.
- Functional design of various future-use scenarios.
- Recognition of a part of a fixed structure, supporting various flexible scenarios of changes in the usable part – separation of the fixed and variable parts.

Prefabrication, industrialization of systems production that strengthens the separation of systems and block replacement of systems.

These resources are used for future spatial changes – physically, utilitarian and aesthetically [15, 20–22].

**Criteria for assessing the introduced solutions enhancing flexibility**

As shown by A. Saari and P. Heikkla [23], flexibility is not a universal feature for all types of buildings. There can be no indication of universal and exhaustive goals and criteria for flexibility. Detailed criteria for introducing the principle of flexibility in buildings are relative and closely related to their initial function and scenarios of their conversion to other functions in the future. The method of assessing the criteria selected in a given case may be the measurement between the number of units needed to build a building and the units needed to introduce a variable function to it. The measurement takes place in two variants – a). "X" – taking into account solutions designed in the building that favor flexibility b). "Y" without taking into account such solutions. The degree of flexibility in meeting a given criterion can be expressed as a percentage as a result of the equation $100\% - x/y$.

## 2. Research methods

The basic research method was the method of research by design, the methodological foundations of which were adopted in line with recognized scientific publications [24–28] (Popovic V., 2005, Niezabitowska E.D., 2014).

The research was divided into the pre-design part, the preparatory part, and the design part as shown on Fig. 2. The pre-project part consisted of compiling the theoretical material of the problem, collecting data related to the investor's preferences related to the determination of the assumptions for the size and standard of apartments, planning data, and context analysis. After its completion, the step of summing up – defining project goals, collecting conclusions, and developing requirements for the design and research part took place.

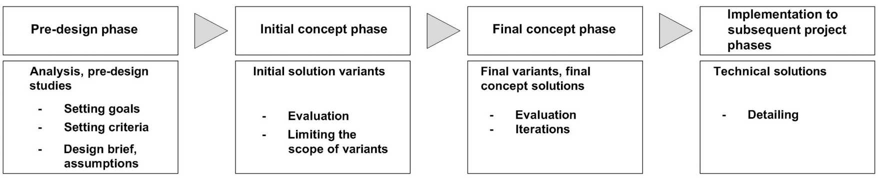


Fig. 2. Scheme of the research process; source: Author's study

Part of the research by design was based on a variant design response to the defined goals and requirements, and on subsequent iterations of solutions. There were variants of parallel solutions for the main body of the building, structure, arrangement of the core and elevator service, as well as solutions for the layout of common spaces and types and scenarios of potential arrangement of housing units. Each variant of the body was checked in terms of distribution patterns of the designed types of flats on a story. Variants of solutions and their iterations at the stage of conceptual solutions were each time assessed by a working team: a design team consisting of architects and industry engineers: structural and installation designers, solution valuation specialists, and the investor's team including specialists for technical solutions, for lease and commercialization.

In order to estimate the costs, the leading variants of solutions were refined to the extent that they could be valued by several system suppliers or subcontractors. After the multi-criteria evaluation and formulation of conclusions, the leading variants were iterated, gradually narrowing down the solutions and detailing the technical solutions until the final solution of the concept was obtained, and implemented in the construction, tender, and executive design phases.

## 3. Results and the course of the research

### 3.1. The pre-design phase

The methodological basis of the work was to identify the client's needs and design strategies favoring the achievement of flexibility, which can be used during research by design. The initial assumption was the division of systems and space as well as programming of soft portion – subject to-change and hard portion – permanent use, within which future changes will take place [19]. Initially, it was necessary to develop a degree of freedom – a framework within which functional changes will be possible. In this respect, the initial assumption was to obtain such a design solution of the structure that would not be modified during changes in use.

The following range of soft parts and possible functional changes were also assumed:

– for the underground part, functional changes consisting of the exchange of use from the parking lot from cars to the bicycle parking lot and vice versa,
– for the ground floor, flexible arrangement of entrances to the building, enabling separation of entrances for two separate parts of residential stories – a possible number of flats for rent covering the lower half of the tower part and a lot of apartments sold individually located in the upper part of the tower part, or one common entrance in the scenario selling all apartments individually.

Additionally, a flexible arrangement of entrances from the ground floor to services was asked:

– for part of the podium: ground floor, first and second floors, change of service functions between gastronomy, trade, offices, and amenities for residents: coworking, spa, gym, bar, lounge,
– for some residential areas: changes involving the introduction of various configurations of the types of apartments and the possibility of constructing two-story pent houses on the top floor.

The diagram of the division of the building into portions soft and hard portions and spaces is shown in Fig. 3.

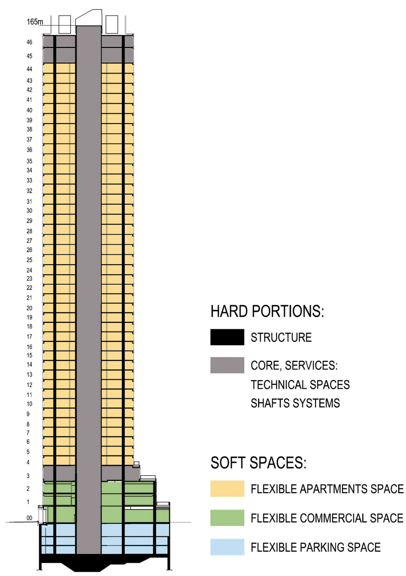


Fig. 3. Diagram of soft and hard portions and spaces of building; source: Author's study

### 3.2. The design phase

The design work was carried out on the basis of variants and iteration of solutions in successive approximations and multi-discipline detailing. In the design phase, in the first step, the initial body of the building was defined, as well as the division and estimates of the size and distribution of the surfaces of the soft and hard parts. The following was initially determined:

– maximum possible number of users,
– the model of the types of the smallest possible housing unit and, on this basis, the largest possible number of apartments in the building.

On the basis of the assumed largest number of users and the greatest possible demand for utilities for the assumed service functions, utility balances were calculated, maximum possible loads were assumed, and elevator analyzes were carried out. This allowed for the preliminary design of the hard part of the building: determining the number and arrangement of technical floors and the size of installation shafts in the core of the building, and the arrangement of elevators and staircases. It has been estimated that the maximum possible number of housing units is 900. As a result, a preliminary model of the shaft and layouts was obtained, as well as a division into hard and soft parts, on which further iterations and detailed work were carried out. As part of them, a study was commenced combining the optimal spans of the structural system in terms of the flexibility of the parking part and the flexibility of apartments, the study of the distribution of installation risers serving the soft part in various apartment configurations, and the study of the facade module and the apartment module.

A layout of the elaborated hard part is shown in Fig. 4.

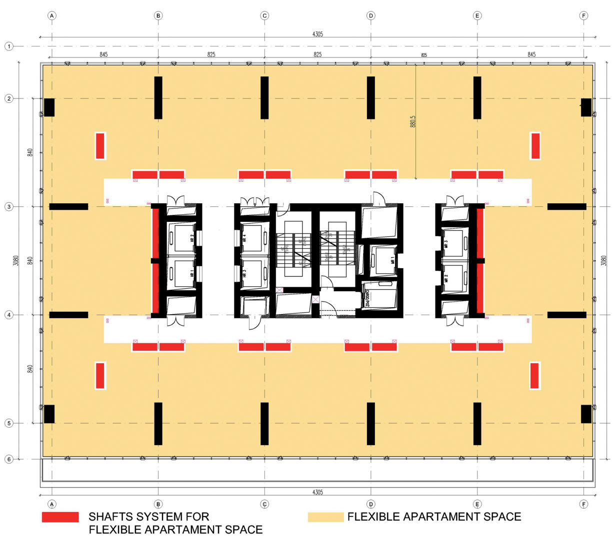


Fig. 4. The layout of the tower portion indicating hard and soft elements and systems; source: Author’s study

The research was based on the determination of the number of types of flats, their variants, and scenarios of the distribution of flats on the floors of the building. The first phase of the study ended with the development of 4 types and 11 variants of 1-room apartments, 12 types and 23 variants of 2-room apartments, 3 types and 5 variants of 3-room apartments, 1 type and two variants of 4-room apartments and one type of 5-room apartments, and two-story penthouses. The matrix of types and variants of apartments is shown in Fig. 5.


Fig. 5. Types and variants of apartments as the base of developed flexibility solutions; source: Author's study

Selected variants of compiling types of apartments into layouts on residential stories are shown in Fig. 6.

Based on these scenarios, the solution of the hard part was detailed to determine the optimal layouts and variants of apartments for the scenarios:

- the span of the structure and dimensions of supports,
- arrangement of risers for installations and the method of access to risers for common communication,
- elevation module.

In the next step, the solutions were verified with regard to the criterion of carrying out building works, refurbishments, and maintenance in the future. They consisted in ensuring access to installations, transport of system elements during replacements and

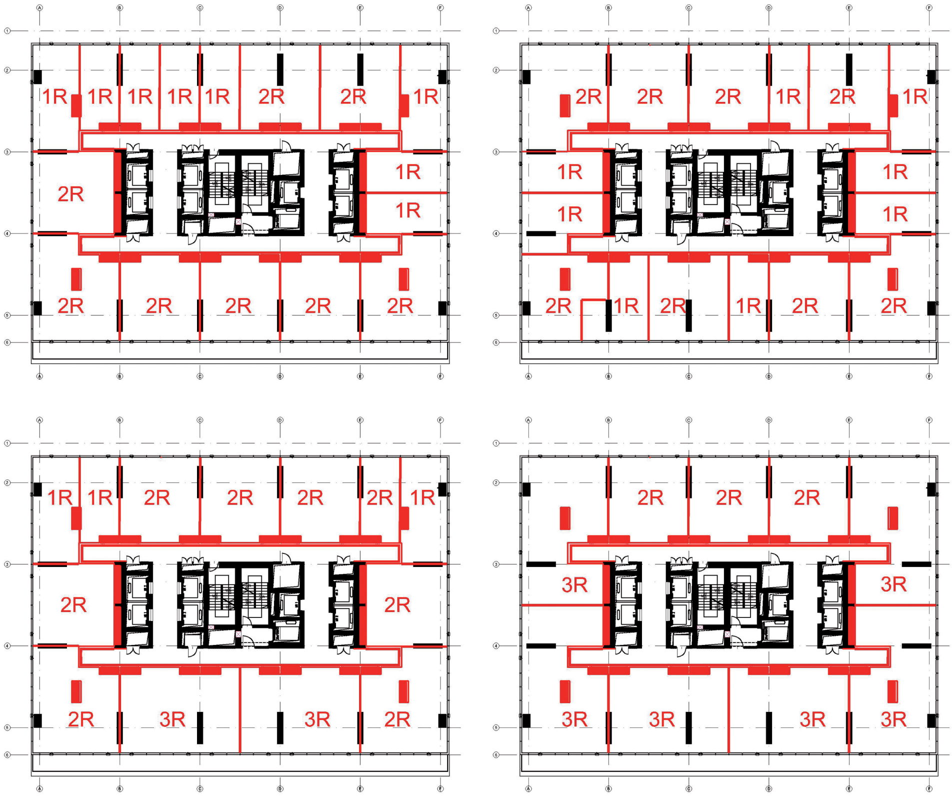


Fig. 6. Examples of variants of the setup of types of apartments on the tower floor. Other combinations of mixing of apartment types on floors were also possible. No of rooms marked on the layout; source: Author's study

reconstructions, as well as ensuring the transport of construction materials, waste and construction works after building completion, as well as providing a flexible strategy of changes in the scope of metering the flats, or the number of apartments.

Based on the results developed in the above steps, economic assessments of the profitability of introducing solutions were made. It was examined whether a rational limitation of the assumed initial degree of freedom could lead to greater implementation savings. The study which consisted of the design variations done by architect, checked by the commercialization specialist and calculated by cost engineers showed that reducing the number of scenarios for the arrangement of flats on floors and variants of the types of flats by the least probable in terms of sale and commercialization may result in rational savings in the costs of facade and structure construction. Smaller façade module allowed for more flexibility and introducing more types of apartments as the number of possible locations of internal apartment walls and wall dividing the apartments is greater. Nevertheless the smaller module makes the façade more expensive as the amount of aluminum profiles necessary to construct the façade is greater – Fig. 7.

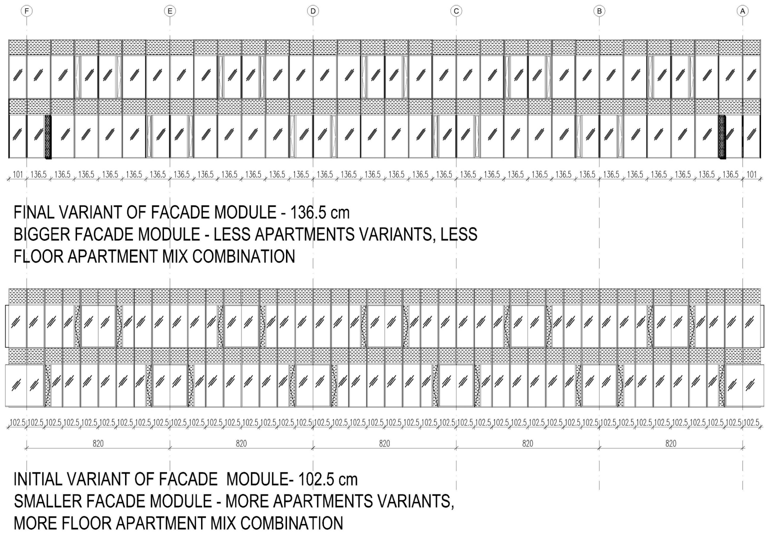


Fig. 7. Façade module optimization; source: Author's study

As a result of the survey, the size of the elevation module was increased due to the savings on façade construction calculated for c.a. 1 500 000 pln. At the same time the shape of the pillars was changed into elongated wall sections: while slightly limiting the flexibility of solutions the saving was made on the amount of the reinforcement of the slab.

At the same time, for sales reasons, the reverse choice was made – that is, increasing the possible loads on the residential floors, enabling the construction of walls between the premises as brick, 18 cm thick, instead of plasterboard skeleton walls, due to the sales value.

## 4. Discussion

Environmental awareness is nowadays the driving force of flexibility. Flexibility allows buil-dings to meet sustainability and is part of the SuCo – Sustainable Construction concept by rationalizing building resources, energy and reducing waste [29–32]. In view of contemporary environmental requirements and goals, it is now logical to design for flexibility of use – to introduce solutions that anticipate the variability of functions, exchange of systems by introducing modularity, prefabrication in implementation, and in designing activities taking into account various functional scenarios of the building, zone separation, separation systems. Certainly, the increased life span of the building will be a derivative of, among other things, its functional flexibility.In terms of research, it is worth noting that the flexibility of a building cannot be achieved without the durability of its structure and materials. As indicated by the research of W. Drozd & M. Kowalik, this is of particular importance for residential buildings, exposed to frequent changes in equipment and intensive use [33]. The flexibility and durability of the structure are the basis for the possibility of introducing changes to other levels of the building systems. It allows the replacement of installation systems, partition wall layouts, materials, and other secondary construction elements. Conducted investigations showed that the most common principles of flexibility are the recognition of the timeline of changes of specific building components and systems, regularity of layouts, the use of light or mobile partitions, redundancy in loads and access, identification of specific zones for service and technical areas, and redundancy and inspection of the equipment.

Among the factors influencing the implementation of the flexibility principle, the conducted research confirms the observations of N. Israelsson & B. Hansson [9] that the most important is the awareness of decision-makers: the investor, designers, project managers, and general contractors, financing conditions, planning future usage scenarios and building life, accepted standards of installation service and materials. Among these roles, Sobieraj et. al. also name contractors managing companies and general contractors [34]. At the same time, the features of residential buildings stand out, which are determined by dedicated solutions favoring flexibility. There is a need to define a denser network of points with access to services – sewage and ventilation, and specific metering and distribution of utilities, which result from the necessity to establish the largest possible number of residential units, and a smaller facade module, which, for example, for flexible office buildings is min. 135 cm [34].

## 5. Conclusions

A noticeable result of the work is the conclusion that greater flexibility and a greater degree of flexibility and freedom in functional solutions in the future are associated with higher investment costs. In order to estimate the acceptable balance between flexibility and expenditure, it is advisable to carry out design works with the participation of value engineering specialists and to conduct valuations of individual variants of solutions. An example of the results of this type of iteration are:

– Analyzes of the facade module, which was a derivative of the analysis of the possibility of introducing a wide number of types of apartments. The resulting façade module of 103 cm and the façade design were appraised and the costs were optimized. The module was increased at the expense of reducing the possible combinations of apartment types from 103 to 130 cm, at the same time savings in the cost of the facade were achieved due to the reduction of the number of aluminum profiles of the facade.
– Analyzes of the structural layout, which were carried out in parallel with the study of the flexibility of the structure in terms of the flexibility of the apartment layout. The analyzes showed that despite the fact that the column-plate scheme for supporting the space around the stems is a more flexible system, for optimization reasons, the variant with elongated columns was selected, which bring savings in terms of implementation, limiting the number of possible combinations of the layout of apartments in the future to the selected, most likely commercially possible.

– Analysis of the material of acceptable partition walls between premises. Analyzes have shown that, due to commercialization reasons, the preferred solution for walls between premises is brick walls. Despite the fact that the lightweight walls meet the acoustic requirements of the code PN-B 02151-3: 2015-10 – R'A1 50dB standard and are more advantageous due to the lower loads on the structure, greater loads were assumed than the masonry walls between the premises in places of their possible introduction. In this case, a construction allowance was assumed and the flexibility of the building was increased after cost and sales facilitation analyses.
– Designing for flexibility will be more effective if the phasing of the design is clearly defined and the consideration of flexibility is started with early conceptual solutions. This allows for the integration of solutions between individual building systems and reduces the time for the overall design of the facility.
– Designing in terms of functional flexibility should be carried out with the participation of rental and commercialization specialists who can assess the most likely, in terms of market popularity, functional layouts of apartments and the structure of the layout of apartments in the building, which allows for the narrowing of future scenarios of changes to the most probable and keeping the balance between flexibility and costs.

From the point of view of the specificity of designing multi-family high-rise buildings, the introduction of functional flexibility is associated with addressing the following design aspects:

– Adopting a design solution that takes into account flexibility aspects. The area of detailed works already at the concept stage, in addition to the main structural system, is the storeys of the lower parts of the building, where flexibility may be disturbed by larger dimensions of the supports than in the higher parts of the building. This situation requires adopting a balanced solution by carrying out analyzes, selecting possible types of apartments and the type of structure.
– Carrying out detailed analyzes of functional scenarios and principles of installation service and adopting larger sizes of zones and installation lines, which in this case are zoned due to the height of the building. The arrangement of larger lines for carrying out a set of installations must be associated with the analysis of the concept of zoning the installation and the optimal arrangement of technical rooms in high-rise buildings.
– It is necessary to take into account and solve the aspect of the more difficult introduction of system elements into the building during implementation and during the reconstruction of the facility. In this regard, it is necessary to analyze and predict the possibilities of routes for introducing devices, conducting renovations, places for the delivery of materials and elements during reconstruction, and the possibility of reconstructing a part of the building (e.g. a fragment of a story or the entire story) limiting the operation of the entire building as little as possible.

The conducted studies indicate that the main barrier to the implementation of the flexibility principle is the tendency for designers, builders, and investors to perceive the building as a permanent, unchanging structure, and the belief that such solutions are unprofitable, which is consistent with the observations presented in the literature [29, 36]. One can formulate a hypothesis that although both of these beliefs are related to the awareness of the decision-makers regarding flexibility, they may be partially eroded in the future – as the functional changes in the constructed resource of objects appear. Insufficient cooperation between decision-makers is indicated by H.J. Habraken as the main factor in marginalizing or ignoring the issue of flexibility of residential buildings in design practice [37]. A negative factor in the perspective of Warsaw is also inflexible planning regulations – they do not take into account changes in the main functions of the facility during its use, although the principles of flexible buildings and the vision of no demolition are an extremely favorable situation in terms of the city's operation. It is also possible to point out the lack of a comprehensive, multi-criteria methodology for assessing the flexibility of buildings. Although the first theoretical works are being developed, which propose the FlexD index to assess the flexibility of buildings and projects, it is based primarily on cost simulations [23] without taking into account the benefits in other areas related to the construction and maintenance of the building – e.g. time gains and environmental gains. An overall assessment could be useful in assessing the greater value of a building that can be considered flexible in use and contribute to the widespread application of flexibility principles in the investment process. The assessment could also be an independent system analogous to environmental assessments such as BREEAM or LEED or be included by these systems as part of the criteria.

The conducted research process shows that functional flexibility, which was the subject of research for a residential building, is advantageous especially for financial reasons in terms of sales – because it allows offering a custom-made in terms of size, location, and the number of rooms. The client can participate through a greater choice to participate indirectly in the design process because his decisions will result in a different final structure of apartments in the building. They can also participate directly – by making changes to the arrangement of the type of apartment they choose.

As noted by Saari and Heikkila, adaptability and the possibility of change are becoming of the key parameters for the rental business [23]. As a result, in the face of the upcoming changes in the housing market in Warsaw, flexibility becomes one of the key design aspects for economic reasons.

Flexibility, although it has been the subject of research and theoretical studies for many years, in modern reality requires more attention as a design and investment issue. However, housing flexibility remains continuously explored based on different variables which still change , so both possible usage, goals, criteria, and tools for implementing flexibility should still be the subject of investigation. As far as analytic, and digital tools are concerned, their development will affect the speed and number of possible iterations already on early design solutions. Facilitating the calculation and evaluation of solutions will facilitate multi-criteria decision-making and the process of considering variants of functional scenarios, which will affect the better possibilities of developing optimal solutions related to the implementation of functionally flexible buildings.

Flexibility is a feature that modern buildings need – due to the more and more dynamic changes in use and technology. The boundary of a contemporary, modern building is constantly shifting in terms of equipment and response to environmental challenges. Therefore, the problem can be posed in the opposite way: the non-flexibility of buildings will be eliminated in the investment, design, and implementation practice. This is especially important in light of the adoption of the New European Bauhaus program, the key part of which is the CE postulates for Circular Buildings. Flexibility, in turn, is an inherent requirement for the realization of a truly functioning CB as its effects are potentially capable of closing the loop of the Life cycle from Buildings.

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# Badania przez projektowanie: elastyczność funkcjonalna wysokościowego budynku apartamentowego zlokalizowanego w Warszawie

**Słowa kluczowe:** adaptacyjność, budynki mieszkaniowe, elastyczność, wysokościowiec, Warszawa

## Streszczenie:

Tekst poświęcony jest opisowi metodologii oraz badań przez projektowanie służących określeniu rozwiązań sprzyjających elastyczności funkcjonalnej budynku wysokościowego położonego w Warszawie przy ul. Grzybowskiej. Praca przedstawia tło teoretyczne oraz prowadzone badania i ich metodologię. Zakres rozwiązań związanych z elastycznością funkcjonalną dotyczył wymienności funkcji usługowych w części podium budynku, zmian użytkowania parkingu oraz zapewnienia możliwości zmian w układzie typów i wariantów typów mieszkań na piętrach. Prace badawcze prowadzono w fazach: przedprojektowej i projektowej. Określono cele i kryteria rozwiązań oraz prowadzono prace badawcze poprzez iteracje i sprawdzanie pod względem opłacalności rozwiązań. Przyjęte rozwiązania polegają na zaprojektowaniu optymalnej części stałej budynku – trzonu, układu konstrukcyjnego, rozmieszczenia stref i pomieszczeń instalacji oraz zastosowanie naddatków konstrukcyjnych i przestrzennych. Wypracowano optymalny moduł fasadowy. Badania mają na celu przybliżyć praktyce projektowej problematykę elastyczności które współcześnie jest istotna ze względów ekonomicznych i środowiskowych.

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