OPTIMIZATION OF TYPOLOGICAL REQUIREMENTS FOR LOW-COST DETACHED HOUSES

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Abstract
The presented paper deals with an analysis of the legislative, hygienic, functional and operational requirements for the design of detached houses and individual dwellings in terms of typological requirements. The article also presents a sociological survey about the preferences and subjective requirements of relevant public group segments in terms of living in a detached house or an individual dwelling. The aim of the paper is to define the possibilities for the optimization of typological requirements. The optimization methods are based on principles already applied to contemporary detached house preferences and trends. The main idea is to reduce the amount of floor space, thus lowering construction and operating costs. The goal is to design an optimized floor plan, while preserving the hygienic criteria for individual residential dwellings. By applying optimization methods, a so-called rationalized and conditioned floor plan results in an individual dwelling floor plan design that can be compared to a reference model with an accurate quantification comparison. The significant sources of research are the legislative and normative requirements in the field of house construction in Slovakia, the Czech Republic and abroad.

Key words
- Typology
- Individual dwelling
- Optimization
- Rational detached house
- Low-cost detached house

1 INTRODUCTION
The current economic situation and the prices of detached houses or individual dwellings and apartments in the real estate market, as well as the overall development of society attract us to the idea of rationalizing the design of an individual dwelling that would be cheaper or comparable to a similar apartment in the city. The design of such a dwelling should be characterized by its economic availability with regard to the initial costs as well as its subsequent operation, with the possibility of its construction in phases.

The initial construction phase as well as the possible subsequent stages of the construction of an individual dwelling should not place disproportionate burdens on prospective owners at a high cost, which would make it impossible to build. The optimization process should be applied to the layout design in terms of the size of the usable area. Individual requirements for an operational solution, an architectural solution and, consequently, a design solution create the prerequisites for an optimal evaluation of the initial investment. The aim of this paper is to find an optimal typological design solution for an individual dwelling for its overall rationalization.

1.1 Analysis of the historical forms of housing and their typology
The history of habitable houses in the present-day Slovak region began around 5000 B.C. (Pavúk, 2012) An analysis of the historical development of housing and the development of their layout designs
suggests there has been a long-lasting and continual development of settlements within our geological and social borders. At all stages, efforts have been made to create rational floor plans and, consequently, the volumes of the individual forms of residential buildings, taking into account the possibilities of society in a given historical period. The common features of the historical forms of housing are a longitudinal form and an appropriate orientation. Characteristic of these forms is an effective layout and versatile solutions, taking into consideration possible changes in the number of householders or other dispositional changes. Historic forms of housing are characterized by a rational approach without wasting unnecessary space.

Later in the 20th century, the primary objective in the theoretical concept of functionalist architecture was a purposeful intention to introduce scientific methods and procedures into architectural work. The introduction of industrial construction methods and the achievement of operational and building economics and hygienic standards led to the application of modern structural systems to create an architectural morphology and incidence (Titl, 2002). The Functionalism Program not only sought the optimal functioning of a home or apartment but also a new scientific approach to design solutions. The functionalist method of design is based on operating schemes, room and service linkage, an adequate orientation, and hygiene requirements (Haas, 1978).

1.2 Reference buildings

Current trends to optimize the cost of individual dwellings and detached houses are manifested both by reducing the area of the house as well as optimizing operating costs. Detached houses are designed and constructed to reduce their energy consumption and environmental burden. However, when discussing the reduction of an area, it is important to add that the goal of this paper is not to define a minimal house but an optimal and rational house that maintains operating standards.

In observing current trends applied to the design of individual dwellings and detached houses, it is possible to name the basic possibilities in the actual realization of detached homes based on layout solutions:
- variable or reduced height of ceilings
- simplifying the layout of the rest area
- work with sliding walls or modifiable fixtures

Another trend focuses on flexible houses, which allow for immediate floor plan changes with regard to actual requirements. The elements of saving or rationalization trends in the layout of individual dwellings are oriented towards simplifying layout schemes to a certain intersection of typological types between an individual dwelling, a detached house, and a cottage, in order to optimize and rationalize habitable structures in general. The result is saving space based on the layout design.

1.3 Current condition

A housing unit consists of habitable rooms or a set of rooms with accessories arranged in functional units, with its own enclosure and intended for permanent living. A habitable room must fulfill various hygienic criteria based on national legislation. Research was undertaken to compare the minimal requirements for the head height of a room and the floor area of the rooms in the following countries: The Slovak Republic (STN-734301, 2005), The Czech Republic (ČSN734201, 2004), Austria, Switzerland (Ramentwicklung, Institute fur, 2006), France, England (Institution, 2006), Italy (Decreto Ministeriale 5 Luglio, 1975), Germany (DIN18011, 1967), The USA, The Netherlands (Bouwbesluit, 2003), Hungary (253/1997, 1997), Spain (Condiciones Higiénicas Mínimas que han de reunir las Viviendas, 2016), Lithuania, and Finland (132/1999, 1999). The results are listed in Tab. 1.

The data differs regarding local conventions but can be considered to be comparable. These regulations legislative defining the minimum standards for the housing optimization design process. However, in a number of countries the recommended or minimum dimensions for housing units are not legally defined.

When considering the optimization of a design of an individual dwelling, it is necessary to remember to apply a suitable form of an individual housing ensemble in the structure of residential complexes. The classic “urban sprawl” problem does not apply to intended optimization methods and rationalized solutions in the field of individual dwellings and detached house design.

1.4 House functions

The concept of housing is distinguished by three basic functions:
1. Biological Function - represents the basic biological needs of a person such as sleeping, resting, eating, hygiene, sexual life, physical care, and care of children
2. Maintenance function - represents activities associated with maintaining a place of residence such as preparing food, keeping order, cleaning, washing, storage, etc.
3. Social Function - focuses on gatherings and social interaction such as visits, leisure activities, study, education, the intellectual work of children and adults, and games.

These also include important aesthetic functions, which are defined by the condition, state and configuration of the internal environment, which are originally defined by the design process of individual dwellings and detached houses (Liščák, 1992).

For each of these functions, the optimal assumptions envision separate functional units and spaces. When optimizing the typological requirements for a detached house, it is necessary to verify the possibility and general desire to rationalize spatial claims, without affecting the above-mentioned functions of a detached house and without interfering with the basic legislative and hygiene standards of interior spaces. In an individual dwelling, without the need to provide care for children and a family, there is assumed to be a greater degree of optimization of the area. Flexibility, the integration of non-conflicting operations, substitutability, and the multi-purpose usage of individual spaces create the prerequisites for the optimization of individual dwellings and detached houses based on an initial operating design.

2 METHODS

The optimization of typological requirements, and the functional and operational principles in the design and construction of individual dwellings and detached houses, with regard to the saving of useful floor area in the layout design of individual housing is based on:
- An analysis of the historical development of layout solutions for detached houses
- An analysis of the current rationalization trends
- An analysis and comparison of legislative conditions and limits of layout solutions in different countries
- An analysis of house functions and the typology of habitable spaces
- A definition of basic options for optimizing the layout design for individual dwellings
A sociological survey to determine the preferences of respondents for requirements in the design of a detached house or individual dwelling

Quantification of possible savings after the optimization process for a typological scheme design

Experimental verification of the proposed optimization operation for a rationalized solution

The hypothesis of the optimization possibilities in the operational design of individual housing is based on the need to preserve legislative requirements, which are supported by a sociological survey. The outcome of the sociological survey shows the acceptance or rejection of the proposed solutions by the public.

3 SOCIOLOGICAL SURVEY

A questionnaire focused on the acceptability of optimization methods for rationalized individual housing designs for a productive-age population; it was applied to a reference sample of 435 interviewees. The range of the respondents was from 18 to 60 years. The sociological survey was conducted from 08.06.2016 to 22.09.2016. The survey, which used a digital questionnaire, was given to respondents from the region of western Slovakia. After a consultation, the wording of the questions was modified to provide clearer understanding. The response options have been modified, and illustrative images and diagrams have been added. The data collection was transferred digitally, using an online questionnaire placed on Google forms.

### 3.1 Sociological survey evaluation

**Question No. 1:** “What is your age?”

Answer: under 30 years - 72%, from 30 to 40 years - 19%, over 40 years - 9%.

Conclusion: almost three quarters of the respondents were young people under the age of 30. They are the ones who most actively addressed the issue of self-contained housing.

**Question No. 2:** “What is your gender?”

Answer: male - 52%, female - 48%.
Conclusion: A nearly equal gender representation was involved in the survey. It is important to state that it was possible not to answer all of the questions.

**Question No. 3:** “How much would you invest in building a detached house?”
Answer: up to 60,000 € - 20.6%, up to 70,000 € - 23.7%, up to 80,000 € - 26.6%, over 80,000 € - 29%.
Conclusion: Most respondents answered that they would invest more than 80,000 € in the construction of a detached house.

**Question No. 4:** “Do you plan to live in a detached house with children?”
Answer: yes – 86.4%, no – 13.6%.
Conclusion: According to the survey participants, a house is thought of as a living space for a whole family. Up to 86.4% of the respondents are considering living in a family house with children. That means that for a certain period of time, the detached house’s occupancy could be doubled.

**Question No. 5:** “How many storeys would you prefer?”
Answer: one storey (ground floor, bungalow) – 39.9%, multi-storey – 60.1%.
Conclusion: Up to 60% of the respondents preferred a one-storey alternative. Bungalows were more attractive to respondents, whether they were living with small children, or when they were older, when walking up and down the stairs is considered tedious.

**Question No. 6:** “Would you be willing to tolerate a less comfortable staircase in a detached house?”
Answer: certainly yes - 5%, probably yes - 19.8%, probably no - 36.2%, certainly no - 39%.
Conclusion: Only 5% of the respondents would be willing to tolerate less comfortable stairs in their detached house. More than three quarters of the respondents were inclined to disagree. Of these, up to 39% did not even think of this option and rejected it altogether.

**Question No. 7:** “Would you agree with less illumination (without a window, with a small window, using a light-guide) in the detached house?”
Conclusion: According to the questionnaire responses, the bathroom is the only room that could be less illuminated in terms of cost optimization.

**Question No. 8:** “Is it necessary for you to have 2 toilets in a smaller detached house?”
Answer: certainly yes – 27.6%, probably yes – 30.5%, probably no – 29%, certainly no – 12.9%.
Conclusion: Nearly 60% of the respondents insist on two toilets in a small detached house. Almost 30% of them would not live in a house without two toilets. Only 12.6% would accept living in a small detached house with one toilet.

**Question No. 9:** “Would you agree to a bathroom and toilet together in the same room in a detached house?”
Answer: certainly yes – 20.5%, probably yes – 25.7%, probably no – 31.2%, certainly no – 22.6%.
Conclusion: The question of whether the respondents would accept a bathroom together with the toilet was divided into two groups. Nearly half of them could not imagine it, and the other half had no problem with it or would be able to consider it in the future. Only the older people tended to respond positively. The younger people (20-30 years) rejected this option.

**Question No. 10:** “Would you be willing to give up direct lighting and ventilation (windows) in the bathroom of a detached house?”
Answer: certainly yes – 6.4%, probably yes – 21.4%, probably no – 41.7%, certainly no – 30.2%.
Conclusion: It is clear that the respondents do not want to give up bathroom windows. Only 6.4% of the respondents would be able to imagine the alternative without a window in the bathroom of the family house.

**Question No. 11:** “Can you imagine a bathroom (without a toilet) as a part of a bedroom?”
Answer: certainly yes – 17.2%, probably yes – 19.9%, probably no – 34.2%, certainly no – 28.7%.
Conclusion: When asked if they could imagine a bathroom without a toilet as part of a bedroom, more than 60% of the respondents answered negatively. Just over 17% of the respondents would accept with such a layout.

**Question No. 12:** “Would a kitchen associated with the living room, dining room and workroom suit you for the purpose of saving space?”
Answer: certainly yes – 42.1%, probably yes – 32.1%, probably no – 19.6%, certainly no – 6.2%.
Conclusion: When asked whether the respondents would accept a kitchen combined with a living room, dining room and a workplace, up to 42.1% of the respondents answered “yes” and 32.1% of the respondents answered “probably yes”. Modern trends in open, interconnected living spaces contributed to this response.

**Question No. 13:** “Would you agree if the bedrooms were directly accessible from the living room or living space?”
Answer: certainly yes – 10.5%, probably yes – 33.8%, probably no – 36.7%, certainly no – 19.0%.
Conclusion: When questioned about direct access from the bedroom to the living room, the respondents were more or less dissatisfied. More than half of the respondents chose a negative answer.

**Question No. 14:** “Would you be willing to tolerate a lower head height in certain parts of a detached house?”
Answer: sleeping space: certainly yes – 22.0%, probably yes – 30.8%, probably no – 28.2%, certainly no – 19.0%; kitchen: certainly yes – 4.0%, probably yes – 12.6%, probably no – 35.0%, certainly no – 48.4%; toilet: certainly yes – 20.7%, probably yes – 37.8%, probably no – 23.9%, certainly no – 17.6%; maintenance room: certainly yes – 43.6%, probably yes – 36.4%, probably no – 14.2%, certainly no – 5.8%.
Conclusion: “Certainly not” is what most of the respondents voted on the kitchen’s height. However, if the maintenance room is just one part of a house with a reduced head height, the respondents would have no problem. In the maintenance room and toilet, the head height could also be reduced.

**Question No. 15:** “Can you imagine using different sliding, lifting, inserting, modifiable or mobile parts of a detached house?”
Answer: certainly yes – 28.0%, probably yes – 29.7%, probably no – 32.5%, certainly no – 9.8%.
Conclusion: A very modern and practical use of space by sliding and modifiable parts of a detached house was not favored by the re-
residents to the survey. The highest percentage of respondents did not agree with the question. The options “certainly yes” and “probably yes” obtained over 50% of the votes. Less than 10% of respondents could not imagine such a possibility.

**Question No. 16:** “Would you be interested in adding, removing, or expanding the volume of a detached house?”
Answer: directly, during the daytime: certainly yes – 24.7%, probably yes – 40.6%, probably no – 27.4%, certainly no – 7.3%; over several years: certainly yes – 38.5%, probably yes – 45.2%, probably no – 13.1%, certainly no – 3.2%.

Conclusion: the majority agreed with the possibility of changing the size and volume of a detached house. Up to three quarters of the respondents would be interested in this opportunity after more than one year of use of a detached house. More than 60% of the respondents would be inclined to use this option directly during the daytime.

The survey highlighted the boundaries that owners of potential detached houses could accept. The answers where the respondents did not issue direct positive or negative feedback testify to the need for individual solutions, which are often an initiating factor in the intention of building their own individual housing.

### 4 RESULTS

In order to quantify the possibility of saving floor space, it is necessary to define the “reference model” of the detached house, which can be compared with the validated solution. Creating such a reference model is challenging, because the specific requirements of the owner are taken into consideration when creating a layout design for an individual dwelling. For this purpose, it is necessary to state that for each individual proposal of the layout, it is necessary to create a separate reference model. The reference model can then determine the theoretically achievable floor space savings, but only for a specific and specified individual solution. It is possible to focus on:

- A market reference model
- An areal reference model

The “market reference model” is based on the price per unit area of the house and the possibilities of the investor; it is then possible to define the possibilities of rationalization of the layout proposal from the resulting affordable surface space. The pitfall of such a model lies in the variable and unstable value of the property price. In the case of an “areal reference model”, it is possible to start with the actual needs of the investor, regardless of the average price per unit area. Subsequently, it is possible to optimize the layout design (while accepting suggested optimization tools by the prospective owners) for specific areal and individual requirements, with the assumption that the optimization solution will not reduce the hygienic comfort and the value of the resulting building. Thus, a quantitative comparison of the theoretically approachable cost savings is only possible with a specific example. It is possible to determine the “standard” reference floor area of individual rooms and then compare the theoretical rate of area savings for a particular design solution using specific optimization methods.

<table>
<thead>
<tr>
<th>Question No.</th>
<th>Summarized question</th>
<th>Acceptable / Not acceptable</th>
<th>Theoretical floor area savings achievable (m2)</th>
<th>Alloqut savings to reference model (%)</th>
<th>Total 23.7% - 37.5%</th>
<th>Note, partial conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Less comfortable staircase</td>
<td>N</td>
<td>0.7-1.9 m²</td>
<td>0.8-2.2%</td>
<td>0</td>
<td>No direct effect on the area</td>
</tr>
<tr>
<td>7</td>
<td>Less illuminated room</td>
<td>Home office N</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>No direct effect on the area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bathroom A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>No direct effect on the area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kitchen N</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>No direct effect on the area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bedroom N</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>No direct effect on the area</td>
</tr>
<tr>
<td>8</td>
<td>Need for 2 toilets in house</td>
<td>A (min.)</td>
<td>1.3 m²</td>
<td>1.5%</td>
<td>0</td>
<td>2 toilets are more suitable</td>
</tr>
<tr>
<td>9</td>
<td>Bathroom associated with toilet</td>
<td>N</td>
<td>1.3 m²</td>
<td>1.5%</td>
<td>0</td>
<td>Also saving space in halls</td>
</tr>
<tr>
<td>11</td>
<td>Bath associated with bedroom</td>
<td>N</td>
<td>2.1 m²</td>
<td>2.3%</td>
<td>0</td>
<td>Also saving space in halls</td>
</tr>
<tr>
<td>12</td>
<td>Kitchen associated with living room</td>
<td>A</td>
<td>2.0 m²</td>
<td>2.3%</td>
<td>+</td>
<td>Also saving space in halls and dining area</td>
</tr>
<tr>
<td>13</td>
<td>Bedroom accessible from living room</td>
<td>N</td>
<td>4.0 m²</td>
<td>4.6%</td>
<td>0</td>
<td>Also saving space in halls</td>
</tr>
<tr>
<td>14</td>
<td>Lower head height</td>
<td>Sleeping space A</td>
<td>14 m²</td>
<td>16.1%</td>
<td>+</td>
<td>Floor area is lower</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kitchen N</td>
<td>8 m²</td>
<td>9.2%</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Toilet A</td>
<td>1.3 m²</td>
<td>1.5%</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maintenance room A</td>
<td>3.3 m²</td>
<td>3.8%</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Modifiable or mobile parts of house</td>
<td>A</td>
<td>12 m²/room</td>
<td>13.8%</td>
<td>+</td>
<td>Time factor</td>
</tr>
<tr>
<td>16</td>
<td>House volume modifications</td>
<td>Directly during daytime A</td>
<td>12 m²/room</td>
<td>13.8%</td>
<td>+</td>
<td>Time factor</td>
</tr>
</tbody>
</table>

The table above shows the range of theoretical floor area savings achievable based on the “Areal reference model” and the sociological survey (author).
4.1 Calculation of the theoretical floor space savings achievable

The reference area can be determined in several ways, for example, based on the recommended area of the housing unit’s rooms (Table 1, e.g.) or on the basis of other requirements resulting from the individual needs of the owner or on the basis of the minimum or recommended needs in other countries. For example, an “areal reference model” house consisting of a living room, kitchen, master bedroom, children’s room, bathroom, toilet, maintenance room, home office, wardrobe and halls can be verified with the application of specific optimization methods. In this example, we assume a reference floor area of 87 m². Specifically, the process can be based on methods for the optimization of the layout design based on variable or reduced head heights, simplifying the layout of the rest area, or working with sliding walls or modifiable fixtures. The form of optimization applied is not always quantifiable, for example, in the case of gradual modifications, where the possibility to customize the layout of an individual home would be evaluated over time. The optimization methods must not reduce the hygienic standards of the owner or legislation for an individual dwelling or detached house; at the same time they must be judged as acceptable by the user. Table 1 demonstrates the range of the theoretically achievable floor space savings based on an “areal reference model” and the broad acceptance of particular optimization methods evaluated in the above sociological survey.

4.2 Particular conclusion

According to Table 2, the range of the theoretical floor space saving achievable based on the “Areal reference model” and the sociological survey is a total of 23.7% - 37.5%. The direct quantification and theoretically achievable floor space saving in the layout design is in terms of theoretical space saving rather than an actual one that depends closely on numerous direct effects. Notwithstanding the theoretical understanding of the proposed rationalization of the theoretical floor space saving, this value is of interest in that it provides the prerequisites for the successful application of individual solutions. Methods for optimizing layout solutions are closely involved in creating a rational individual home. Large-scale savings were particularly noticeable in the field of modifiable and mobile optimization tools. The acceptance of such solutions by the public is also pleasing.

5 EXPERIMENT

The application of the individual disposition models for optimization in direct comparison with the reference disposition model provides a more balanced comparison and evaluation. The resulting theoretical savings of the surface area is both visually and quantitatively comprehensible. From the many models comparing such schemes, “the multi-level on the ground floor” optimization method was chosen to demonstrate a comprehensive comparison.

6 CONCLUSIONS

The results of the theoretical floor space savings achievable and, at the same time, a comparable level of the optimization of an individual dwelling point to the remarkable possibilities of rationalization when designing a specific individual dwelling or detached house. The sociological survey highlighted the public’s reservations about traditional values, but also the need to seek intelligent possibilities for the rational employment of a layout design.

The benefit lies in verifying the acceptability of this optimization method by the public. With the trend of rising costs related to construction, the credit load, heating, and overall operation and construction of a detached house, it is possible to preserve the architectural qualities of a design or to discover new ones.
REFERENCES


