

UPORABA STATISTIČNIH METOD PRI PRILAGODLJIVEM NAČRTOVANJU VEČSTANOVANJSKE GRADNJE

THE USE OF STATISTICAL METHODS IN FLEXIBLE HOUSING DESIGN

Ključne besede

statistični postopki; načrtovanje stanovanjske gradnje; korelacijska analiza; percentilni rangi

Key words

statistical methods; housing design; correlation analysis; percentile rank

Izvleček

Potreba po načrtovani in izgradnji prilagodljive več stanovanjske gradnje je že od 20. let preteklega stoletja pomembno arhitekturno in tehnološko vprašanje. Upoštevajoč principe gradnje je bilo v praksi preverjenih več načrtovalskih prijemov, malo raziskav pa je narejenih na področju upoštevanja uporabnika. Prilagajanja stanovanjske gradnje običajno temeljijo na preprostem algoritmu, ki obliko, velikost, razpored prostorov in izbor materialov določa na osnovi vhodnih podatkov. Članek opisuje postopke načrtovanja osnovane na običajnih statističnih metodah. Razdelimo jih lahko v dve skupini. Prva opisuje postopke s katerimi lahko določimo potreben razpon prilagoditev glede na celotno analizirano populacijo, druga skupina postopkov pa se osredotoča na posameznika. V kakšni meri se loči od povprečja, kaj so njegove posebnosti? Pri tem smo v analizi upoštevali pet ključnih prostorskih parametrov: svetlost prostora, hrupnost, pestrost, velikost in zasebnost.

Statistični postopki so se izkazali kot učinkovito orodje s katerim je možno izluščiti razlike in posebnosti bodočih uporabnikov stanovanj. Zaradi svoje preprostosti in mehanske logike, jih je smiselno vključiti v ekspertno programsko opremo ali aplikacije, ki skušajo potrebe in pričakovanja bodočih uporabnikov vključiti v proces načrtovanja.

Abstract

The article presents the design tools that were developed using common statistical methods. The design tools are grounded on assumption, that flexible housing design should include the specific pieces of data obtained from its future users or residents. Presented design tools are split into two groups. The first group of tools helps to identify the maximum and reasonable scope of variability in the specific living properties and spatial characteristics that housing design and construction should allow. In other words it answers how much variability and flexibility we really need. The second group of tools is focused on the aspect of the individual user. How and how much does the user differ from the average? What are the user's particularities? Five major spatial properties were taken into consideration: lightness of space, noisiness, vivacity, size, and publicity. The parameters were selected from a much bigger list of personal spatial descriptors in order to simplify the tools that were designed in previous studies.

Statistical methods proved to be efficient enough in determining the assumed differences. Due to their simplicity and mechanical logic they can be used in various kinds of professional software or applications dealing with flexible housing design when there is a need to include a future user into a design process.

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1. Introduction

The need to design and produce adaptable housing has been an important technological and architectural issue since the 1920s [Schneider & Till, 2007]. Regarding the actual construction, many solutions have been designed and tested in practice, but very little research and practice has, in fact, been done with the user in mind. Customization in housing as a process is based on a simple algorithm, which interprets particular and actual data in a certain way, hence influencing the shape, size, configuration, or even material choices of the product. We distinguish between one-time customization, which occurs on the point of the delivery of the product to the customer [Pine, 1999], and lifetime adaptation, which leaves certain options opened for the user to decide upon during the buildings' lifespan. In both cases, the architectural design theory and construction practices are lacking suitable tools to collect and interpret the data gained from the user or inhabitant in a sensible and univocal manner.

The variability regarding housing needs and expectations can be either estimated or measured. It is always linked and thus limited to a specific population expected to constitute the future users of a building to be designed. Estimation is usually grounded either on previous market experiences and does not need scientific methods. But measuring the variability requires a much more specific approach, where one must know precisely what kind of information they would like to obtain from the population. The selection of the expected data content and data quality determines the method used to gain both general and specific pieces of information.

In housing design where only one-time customization is required and professional assistance is offered, the need for a systematic treatment of user data is not critical. Usually the contractor displays the selection of choices to the client, i.e. the future user, and the user makes the relevant decisions, with or without the professional help offered. In cases where no help is offered, the possibility to analyse the user

much more intensively and with focus becomes essential. Due to the increasing popularity of web-based user interfaces in various types of economy (e.g. food, clothing, books, cars, furniture) it is expected with great certainty that such an approach is going to dominate in real estate economy very soon. The core structures of such marketing mechanisms are data collection, data processing and real-time responding based on certain algorithms. On the other hand, the systematic analysis of potential users also limits the number of possible choices, ultimately making the design and production of housing much more efficient.

In cases where lifetime adaptability of housing is expected and pre-designed, the algorithms described earlier can provide design solutions based on the change of initial data conditions.

Which data are essential and should be collected on the user side? What is the selection of parameters that would describe the user well enough, but would not be too complicated for everyday use?

The proposed design tools described in this article is grounded on a much larger theme which is usually described as a parametric architectural design. The final form (or current, depending of the type of flexibility) of the building is determined by various changeable parameters. So the form is shaped by the alteration of values of the parameters. The values are usually derived from the site conditions, economy or other external force which should influence the final form of the building. Very rarely the actual user or the resident can influence the parameters, and even if he could, all the choices are simply left to him without any professional help. These methods, on the other hand, try to find the architecturally and spatially important pieces of data from the user and present them in such a way that they can be directly used during the design or performance of the building.

2. Method

The study is based on the study conducted as part of doctoral

work, i.e. the survey on living habits (Blenkuš, 2003). What is new here is the aim to make the method more applicable, to limit the population to a group of expected future housing users, and to focus on the actual relationship between the input data and the architectural response. The selection of living parameters was limited to five instead of 16 parameters [Blenkuš, 2003], and the analysis was limited to statistical methods only. The reasons for such decisions will be presented below.

2.1. Selection of living parameters

Living parameters describe the living habits of a single user – or a group of people if they are statistically analysed. Data are usually obtained through a survey, either by paper or online. The parameters were selected to address the widest possible quality of information focusing on personal, environmental and operational parameters of living [Blenkuš, 2003]. The practical use of data gained through the survey proved that not all information is essential for design work and that, in fact, the necessary scope of information depends on design decisions themselves. The designer first determines the variables to be left open. These can be adjusted during the initial design stage adapted to personal needs or regulated by the users across the building lifespan. In our case, by comparing the technical construction options provided on the market [Schneider & Till, 2007], the selection of choices was limited to:

- number and size of rooms,
- amount of light in particular rooms,
- level of privacy,
- amount of noise, and
- level of vivacity.

These spatial properties can be regulated either by design or by use, with the help of passive or active technical devices. It is important to decide on the amount of flexibility in early design stages, because – as mentioned previously – this decision influences the shape of the user survey. The selection is thus limited to the following living parameters: size, lightness, publicity, noise, and vivacity. Reducing the number from 16 to 5 will reduce the time to fill

in the survey by 60%, while the necessary information is preserved.

In our pervious researches 16 living parameters (name, importance, publicity, adaptability, size, vivacity, lightness, warmth, airiness, smell, noise, position, duration, frequency, time and persistence [Blenkuš, 2003]) were introduced. They were selected in order to be able to describe maximum variability of the living styles, habits and cultures possible. No technical or construction limitations were taken in account. But as the expected population is smaller and less variable (coming from the same cultural background), many parameters appear to vary very little from person to person. In order to make design tools as simple as possible the final selection of five properties was chosen.

Most of five selected properties are very clear what they represent. Vivacity on the other hand is slightly different, because its name by itself does not tell directly what it measures. It's a measure of the amount of sensory information which present in a certain room or a space.

2.2. Selection of respondents

The pieces of information about building's future residents were obtained by the help of a survey form. According to the initial method [Blenkuš, 2003], each person was asked to list the living activities that they wish to perform in their place of accommodation, and each activity is described using five selected living properties. When for example sleeping was listed as a needed activity, it was then described in detail by the amount of light it requires on the scale from 1 to 5 (1 means very dark, 5 very light). Expected level of privacy, tolerated amount of noise, the desired level of vivacity and the required size were also described on a scale from 1 to 5 (1 means very private, very silent, very restrained and much smaller, while 5 means very public, very noisy, very vivid and much bigger). The survey did not ask for a specific required size but if the activity in itself would need bigger or smaller size of space than usual.

When more than one person is expected to use an apartment, the whole group or a group representative

should fill the survey. In cases where there was more than one result describing the expected conditions in a certain apartment (e.g. two or more results from family members) an approximation was made.

At the initial design stage the expected population of people who are likely to buy or rent an apartment in a building to be designed fill the survey. In our case 60 people were surveyed. Targeting the population is very important as it is neither reasonable nor necessary to open the construction to any number of choices, but rather to make decisions regarding the amount and scope of variability based on actual facts. In our case the surveyed people were aged from 20 to 45 and the majority of them had high-school degree.

3. Evaluation of group results

3.1. Correlation analysis

Correlation analysis was performed to learn whether there was statistical background in the group results to base certain design decisions upon. In other words it gives us enough evidence to use specific design elements which can respond to two or more living parameters at the same time. So if there is a proven correlation between publicity and noise (or privacy and silence), for example, then only one flexible design element is needed to address both parameters at the same time.

The correlations were calculated based on the whole population, the average values of all five living properties for each person were taken as the initial piece of information. The result would tell us, for example, if most persons would at the same time prefer bigger and lighter rooms – in this case the correlation between lightness and size would be relatively high. Statistical correlations were calculated using the Pearson product-moment correlation coefficient (PCC).

3.2. Analysis of average values

We have calculated the average values of a certain parameter (size, lightness, privacy, noise, and vivacity) for all of the listed activities. The aim of this process is not to get the

actual average values; we are much more focused on the particularities than on averageness, to learn some general information about the group and its properties. This general information will help us then to reduce the number of required design choices or options in terms of flexibility. What was studied in detail is (a) the trend of the group, e.g. if it tends to be more affected by privacy or publicity, and (b) the shape of the distribution of the activities according to their average values, i.e. if the activities tend to split into groups or are evenly distributed from the lowest to the highest values.

To test the relevance and the general variability of the data gained by our survey we also calculated the numerous and the standard deviation for all activities concerned.

The average values were calculated for each of the five living parameters as a sum of the particular values form the survey for each of the listed activities divided by the number of persons which listed that activity. For example if 20 persons would specify reading as a desired activity at home, we have summed all the values of the lightness of reading and divided it by 20.

4. Evaluation of results

4.1. Analysis of percentile ranks of living parameters

An insight into the deviation of a certain living parameter or activity from the mean value (in our case median value was taken into account) can be learned from the analysis of percentile ranks (Crocker & Algina, 1986). It is sensible and descriptive to use it because it can evidently point out the most specific living parameters and demands of a certain person – demands which vary from the population average the most [Blenkuš, 2003].

The aim was to find out how much a certain person who decided to live in a designed housing unit differs from other persons. All of the activities were taken into consideration. The difference can be examined in both dimensions – according to the living properties, or according to the activities themselves. However, the latter would not give us the

information on the quality of differences but only on its "location" (e.g. which activity differs the most).

To calculate the percentile ranges for each person separately we first need to calculate the average value of each living parameter (based on all the listed activities the person has specified in the survey). Then the average values for all persons (N=60) were ranked in the arithmetical order. The person with the lowest average value of e.g. publicity was ranked with 1 (R1), and the person with the highest value with 60 (R60). Based on the ranking we can now determine the percentile rank for each person. It would tell us the relative position of the person in the ordered list. We selected the relative position to be expressed in the percentage of the population with the lower value of a certain parameter. Thus, the sample size of population would not affect the result.

Enačba 1 / Equation 1

$$P = \frac{(R - 0.5 \times E)}{N}$$

P = percentile rank
 R = absolute rank
 E = number of persons with the same rank
 N = population size

The results would have values between 0 and 1. Value 0.17 means that 17% of population have the average value of the investigated living parameter lower than that of the investigated person. To make the results more architecturally applicable we decided to demonstrate the positive and negative inclinations of a certain person according to all examined properties. To this end, a value of 0 was chosen to designate the population mean value, thus the deviation varies between -0.5 and 0.5. The calculation formula is slightly adapted to more expressive data presentation.

Enačba 2 / Equation 2

$$P_0 = 0,5 - \frac{(R - 0,5 \times E)}{N}$$

P0 = biased percentile rank (mean value = 0)

The percentile ranks of person no. 54 (A54) can be depicted in a bar chart as shown on Figure 1. According

to the percentile ranks, person 54 deviates mostly in lightness, noise and privacy. The person would prefer a very light apartment, with quite a lot of noise tolerated, but also with a lot of privacy. The size and vivacity do not deviate so much and do not need much attention when designing an apartment for this person. A general design solution could be used when addressing these two parameters, but certain specific choices need to be selected according to the quality of light, noise and privacy. In principle, the parameters with ranks which are greater than 25% or lower than -25% should be addressed with particular care. In general (considering the person's average value), this person's rank would not differ much from the mean population value, but upon closer examination, some specificities appear. It is thus very important to not be initially satisfied only with the person's mean value of deviation, as quite often actual differences appear in detail, i.e. regarding only specific living parameters.

4.2. Analysis of percentile ranks of living activities

Contrary to the analysis of percentile ranks of living properties, the ranks of living activities are not measured as a deviation into positive or negative directions from the mean value but as an absolute value. This is because the deviation for each activity is determined from the various properties which do not have an evaluation scale of the same direction – the positive value of lightness for example does not mean the same as the positive value of noise.

To be able to make persons more comparable in terms of selected

activities we chose 17 most common activities and performed the ranking analysis only on them. So the entire population was compared within the most common denominators – the activities more or less most of them share. The calculation method in the first step is the same as in the previous case (see Equation 1). In the next step, we depicted the absolute value of the deviation from the mean rank of the population. The overall equation would be as follows:

Enačba 3 / Equation 3

$$P_0 = \left| 0,5 - \frac{(R - 0,5 \times E)}{N} \right|$$

From Figure 2 one can notice that person no. 53 (A53) deviates from the population in most of the activities. The only activities where the person appears to be close to the population mean values are children playing, washing and bathing. Combined with the information based on the percentile ranks of living parameters, we can narrow down the scope and the quality of the differences of a certain person compared to the population. Activities with a value of 0.0% were not present in the case of this person.

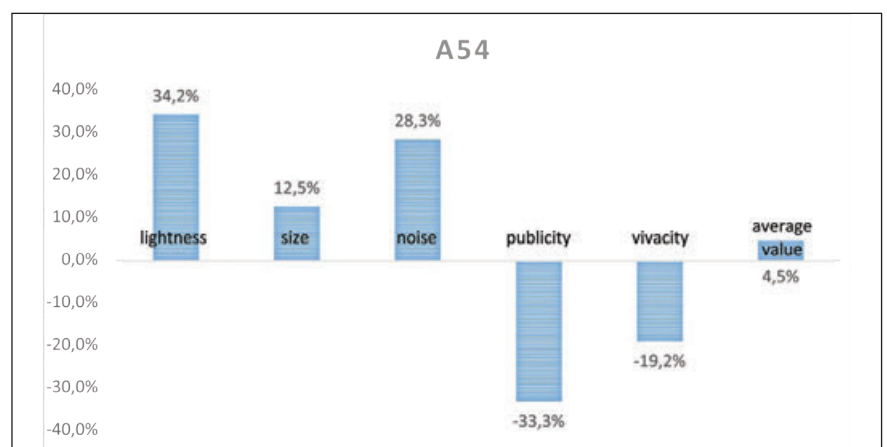
5. Results

5.1. Results of the correlation analysis

As described in the method, the correlation analysis addresses the question whether the measured living

Slika 1: Percentilni rangi parametrov prebivanja za osebo št. 54.

Figure 1: Percentile ranks for the living parameters for person no. 54.



parameters act together in any sort of correlation. The results show a high level of correlation among most of the parameters. Relations between vivacity and noise (0.933) and between vivacity and size (0.918) are particularly high. Compared with the correlation between size and noise, which is also relatively high (0.850), we can conclude that these three parameters work together as a group. This means that when designing for a specific population one can, with great certainty, estimate that the expected adaptations of room size can be designed simultaneously with the level of vivacity and noise. Bigger rooms are more vivid and less disturbed by the amount of noise. In addition, the correlation between publicity and noise should be considered (0.902). That means that rooms or places where we provide a higher level of privacy (are less public) require a more silent environment (are less noisy). In general, lightness shows little correlation with any other parameter, proving that it needs to be designed and controlled independently from the rest.

living parameter	lightness	size	noise	publicity
size	0.615			
noise	0.684	0.850		
publicity	0.557	0.759	0.902	
vivacity	0.709	0.918	0.933	0.848

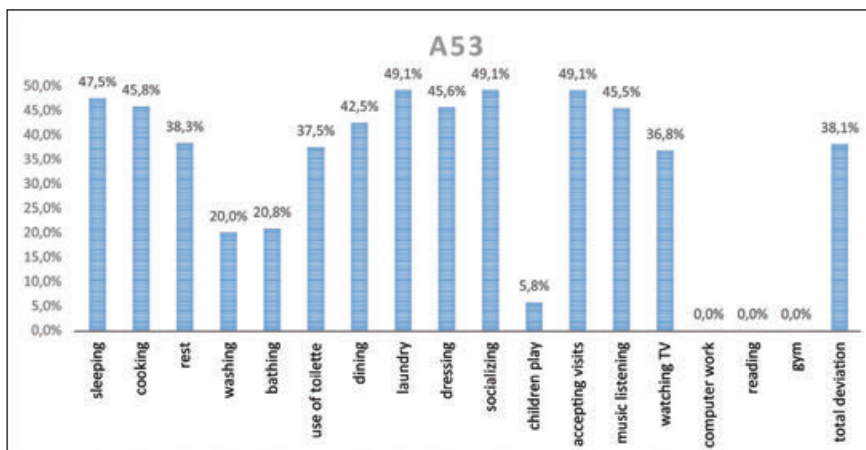
Tabela 1: Povezave parametrov bivalnih parametrov.

Table 1: Correlations between the living parameters.

5.2. Results of the analysis of average values

5.2.1. Size parameter

In general, the average values of the size of each activity shown on Figure 3 are inclined towards higher values rather than lower ones. This is evident because the activities with the average value of the necessary size lower than the mean value 3.0 are in minority. More than three quarters of the activities demand bigger spaces than usual. This is quite important to consider at the design stage of housing, as it is obvious that future residents in general will not be satisfied with the basic or normative sizes of spaces or rooms [ULRS, 2011].



Slika 2: Percentilni rangi parametrov prebivanja za osebo št. 53.

Figure 2: Percentile ranks of the living activities for person no. 53.

5.2.2. Parameter of lightness

Very similar results are obtained when we consider lightness. Most of the activities (about two thirds) require some light. When deciding on an initial level of fenestration in the building, one needs to exceed the normative amount of the required natural light or window sizes by at least 20% to meet the average population expectation. Of course, the amount of light needs to be adaptable for each user or apartment individually.

5.2.3. Parameters of noise, publicity and vivacity

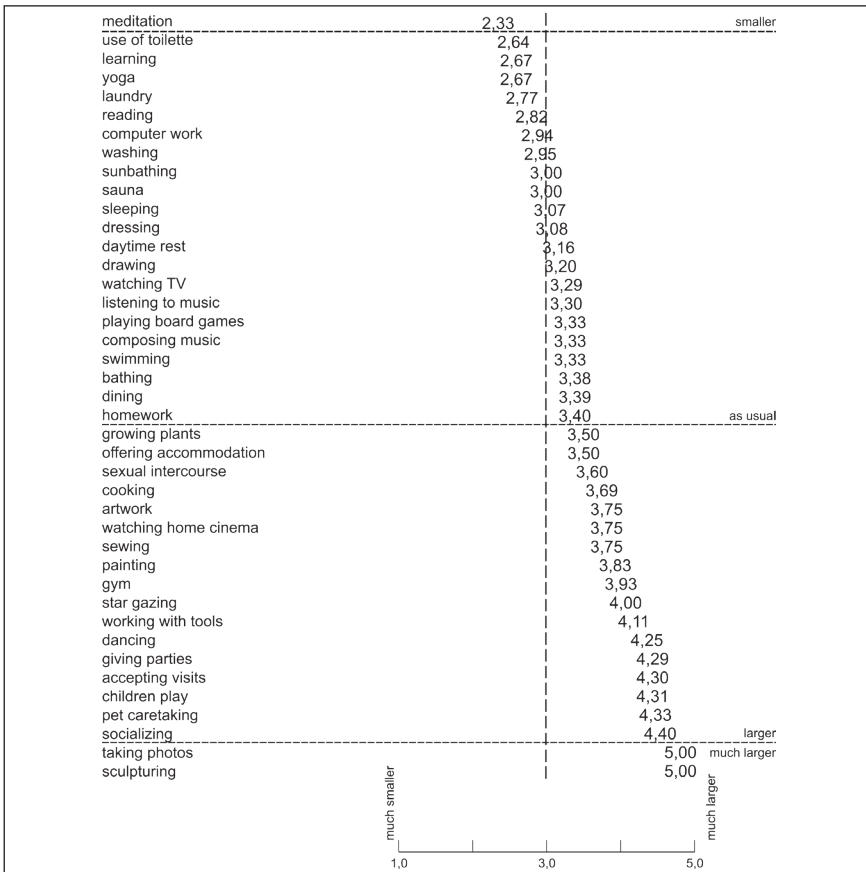
These three parameters can be analysed together, as the correlation analysis revealed that they behave in a group manner. Contrary to the two parameters of size and lightness the sample population shows very low tolerance toward noise in the living environment (see Figure 5). Most of the activities have an average value of less than 3.0 (mean value), which means that they require a more or less silent environment. As a conclusion, the design should allow that most of the activities are separated from the rest. Particularly in the apartments with more than one family member, the overall layout tends to be cellular rather than open. The same conclusions can be drawn from the privacy diagram on Figure 6.

Vivacity is also on the modest side. In architectural terms, this means that rooms and spaces in the apartments will function better with less visual and audial information – with modest, inexpressive design. However, certain variations exist and they correlate well with publicity and noise parameters.

The results gained from the average values for each examined parameter revealed the general bias of the population. On average, the sizes and the level of lightness should be increased, while the levels of noise, publicity and vivacity should be reduced. We can estimate that a general modernist design approach would meet most of the expectations, with a discreet separation of the activities in terms of separated room, alcoves or compartments. To be more precise, the apartments should not be designed as an open space with very little spatial structure but rather with a clear functional and spatial organization. Each activity needs to be precisely positioned in the apartment, grouping of the activities which take place in the same rooms, should address their shared properties. Schneider [1994, X] in his book *Floor Plan Atlas* uses a term "clustering floor plan".

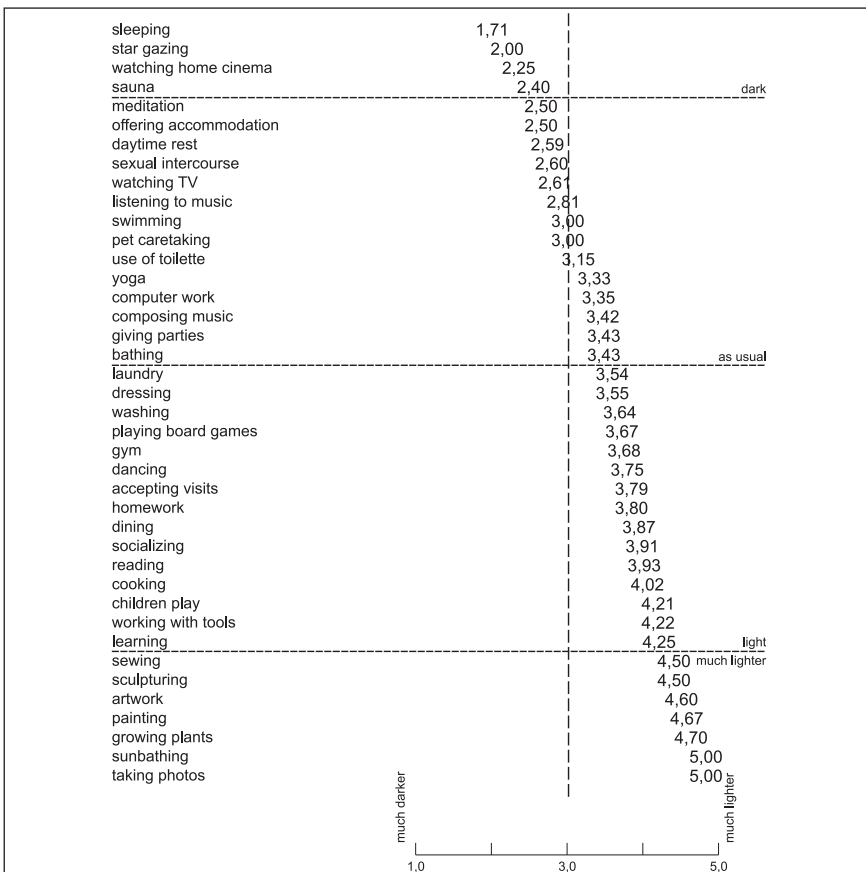
We can also take into consideration the actual values for the most common activities, and design the initial apartments according to those values. For example, if we decide to group bathing, washing and using the toilet in the same room we know that this space would be discreet in design, very private, moderately silent and with a high level of natural light.

However, these are only general determinations. Variability still needs to be provided according to the calculated standard deviation (SD) of the survey results. We will not show all the calculations of the standard deviations but only state that for the



Slika 3: (Zgoraj) Povprečne vrednosti zahtevane velikosti prostora za navedene dejavnosti.
Figure 3: (Above) Average values of the required size of the room for the listed activities.

Slika 4: (Spodaj) Povprečne vrednosti zahtevane svetlosti prostora za navedene dejavnosti.
Figure 4: (Below) Average values of the required lightness of space for the listed activities.



17 most common activities which appear to be desired by most persons the standard deviation is between 0.7 and 0.9. Assuming that the values of all of the persons are distributed in normal distribution, this means that approximately two thirds of population would only require the adaptation by less than one-step up or down on the scale from 1 to 5 for each parameter. In other words, it means that the one-time and lifetime adaptability of the apartments in terms of size, lightness, publicity, noise level, and vivacity do not need to be radical and extreme in options. So if the basic apartment has an average level of lightness, e.g. 3.5 on the initial scale of lightness, than the required flexibility should cover the lightness form 2.5 to 4.5. Consequently a relatively small level of adaptation is enough.

5.3. Results of the analysis of the percentile ranks

5.3.1. Percentile ranks of the living parameters

Percentile ranks proved to be a very efficient tool to become aware of the particularities of a certain person. We randomly chose four persons who will be explained in more detail. Persons nos. 1 to 4 are shown in Figure 8 to Figure 11. These are actually the first four persons who took part in the survey – but they could easily be the actual future residents.

By examining the correlations between the parameters and their average values we gained a good insight into the overall proportions and characteristics of the designed building in terms of its size, openness (fenestration), provided level of privacy, noise protection, and vivacity. However, when we take into account concrete persons we need to be aware of their differences and how those differences can be implemented in the one-time or lifetime floor plan and layout adaptation. In general, the least adaptation is to be considered with person no. 3 (see Figure 10) as the results show that in most parameters the person is very close to the population mean values. The value concerning lightness is above average, which means that the person would prefer to have more light in the apartment than the rest of the

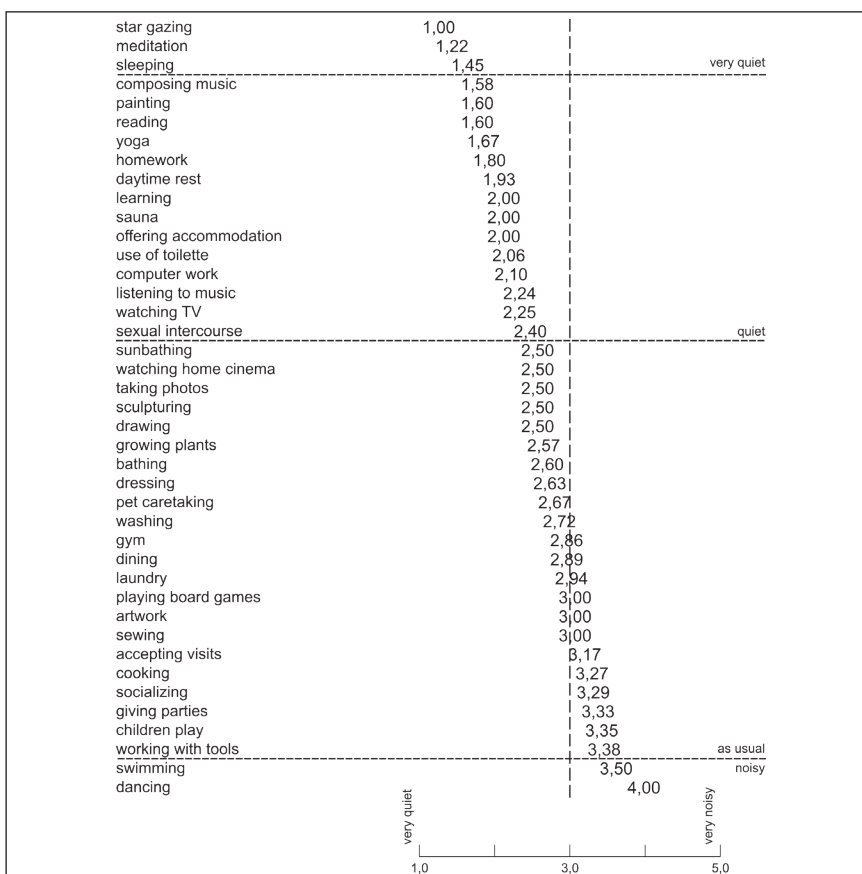
residents. The results of person no. 1 (see Figure 8) deviate in the negative direction in all parameters. This means that the person would prefer slightly less light, less noise, smaller room size and, particularly, a much higher level of privacy. Only 10.2% percent of the population stated the need for a higher level of privacy. This, of course, is a very important piece of information.

Person no. 2 (see Figure 9) is also specific in requiring very private spaces on the one side and very large ones on the other. Regarding both properties, i.e. size and publicity, the data place the person at the very edges of the sample population (values are higher or lower than 40%, only 10% of population showed more extreme results). In a similar manner, we can interpret the results of person no. 4 (see Figure 11). The person would obviously prefer much lighter and bigger spaces than average.

Ranking based on the living parameters is a very simple and efficient statistical tool that reveals the crucial pieces of information about the specific person. Of course, if they are to be interpreted with relative accuracy they need to be compared with the results of the whole population. In other words, they only measure the amount of deviation, not the actual value in itself. However, as architecture is not a precise discipline, particularly when it comes to considering individual personal demands, such an approach can be even better if it provides the designer with a set of accurate data. In the end we, as persons, are more inclined toward interpersonal comparisons (e.g. I'm satisfied because my room is bigger than yours) than toward absolute properties (e.g. I'm satisfied because my room is 22.7 m² big). A designer should take the normative properties of the apartments design [UL, 2011] and then change them accordingly to the results of this method.

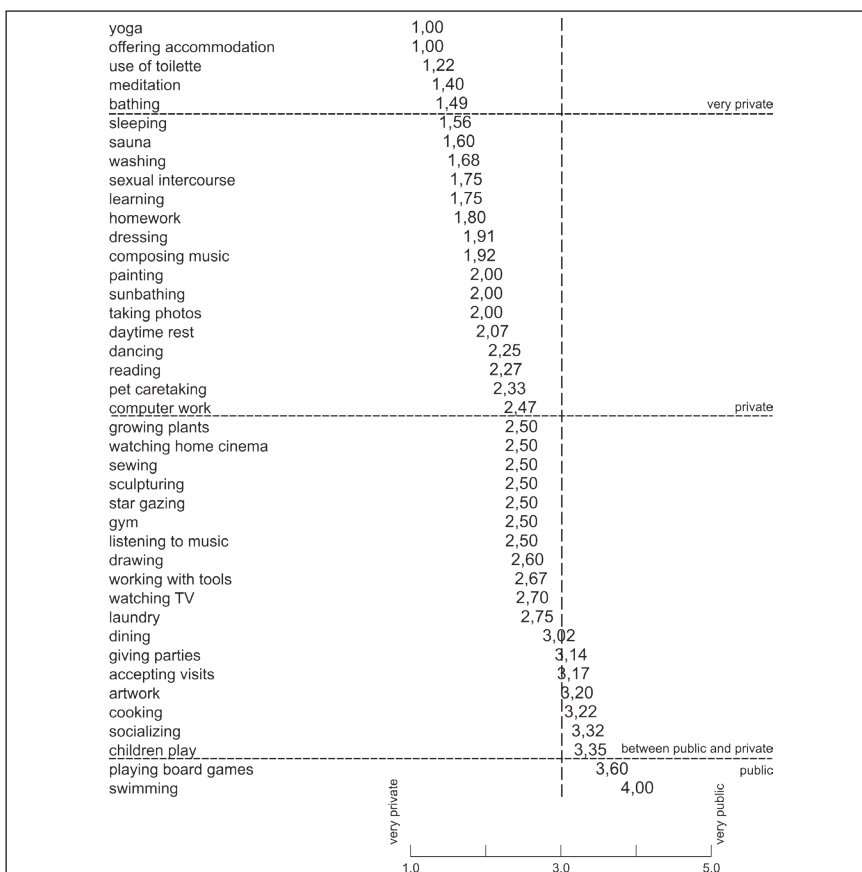
5.3.2. Percentile ranks of living activities

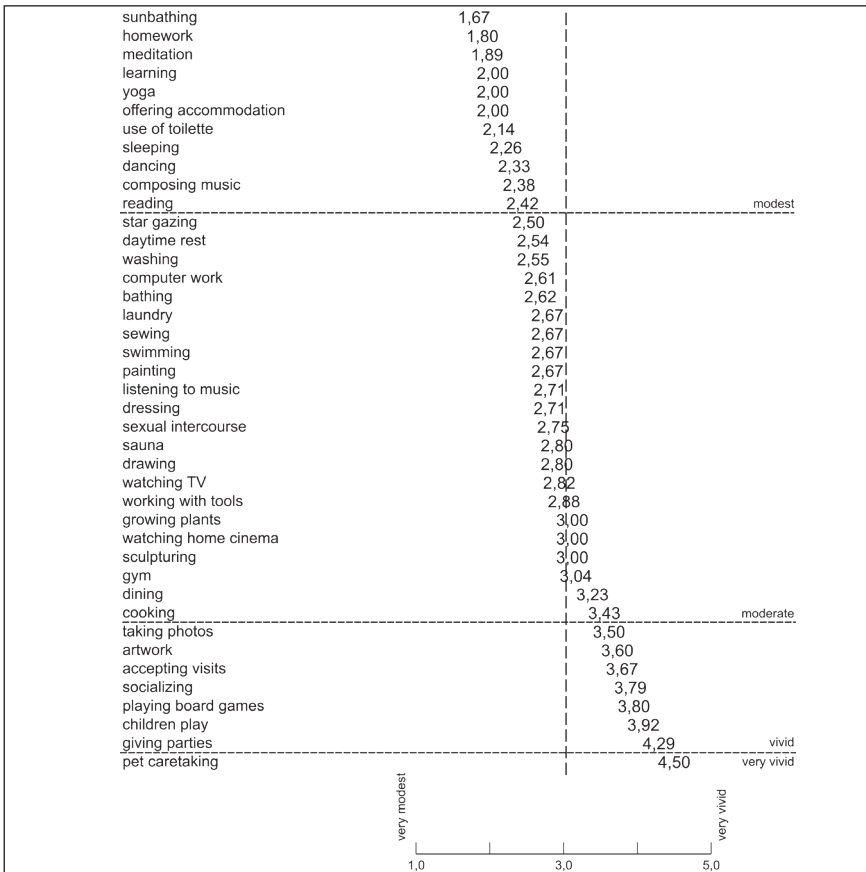
The ranking was calculated for all persons in the survey based on 17 most common activities. The results show the deviation of the living parameters from an average value for each specific activity. Results are not as illustrative as the previous type



Slika 5: (Zgoraj) Povprečne vrednosti dopustne ravni hrupa za navedene dejavnosti.
Figure 5: (Above) Average values of the tolerated noise for the listed activities.

Slika 6: (Spodaj) Povprečne vrednosti zahtevane stopnje zasebnosti za navedene dejavnosti.
Figure 6: (Below) Average values of the required privacy for the listed activities.



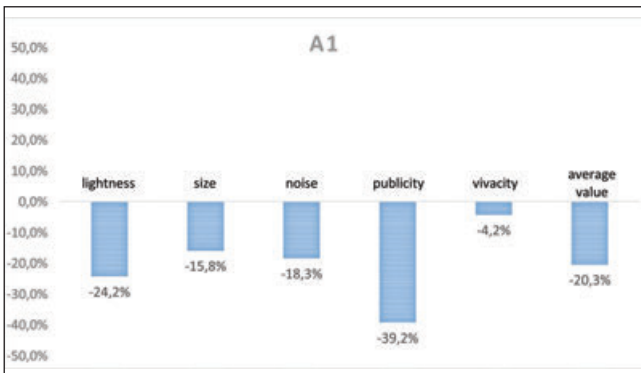


Slika 7: Povprečne vrednosti zahtevane pestrosti prostora za navedene dejavnosti.
Figure 7: Average values of the required vivacity for the listed activities.

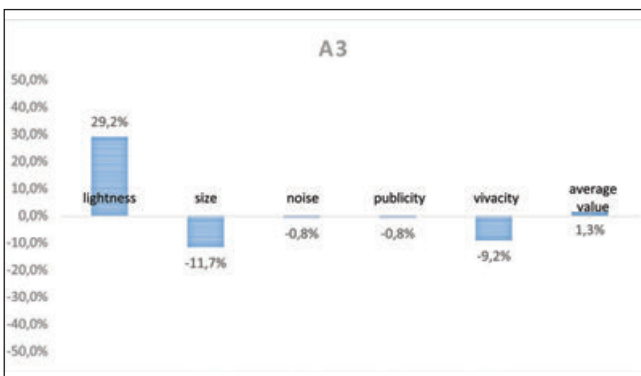
of ranks (see Percentile ranks of the living parameters), as they tend to be confusing. If we, for example, take a closer look at the result of person no. 1 (see Figure 12: Activity percentile rank for person no. 1), there is little concrete information that can be directly used in a design. As mentioned in the previous chapter, this person prefers slightly less light, less noise, smaller room size and especially a much higher level of privacy; we can further conclude that this is true for most of the activities, while only bathing, eating, dressing and reading are close to the population mean values. The activities with a result of 0% were not present at all.

In certain cases when we deal with persons very close to the mean values it can be useful to take a closer look at the activities' ranking, since the parameters do not tell us much. In the case of person no. 3 (see Figure 13) we already found that the person deviates from the population only in terms of lightness. The person would prefer to have more light in the apartment. Looking at the bar chart, we find that this is particularly true for activities of daytime rest, laundry (!), children

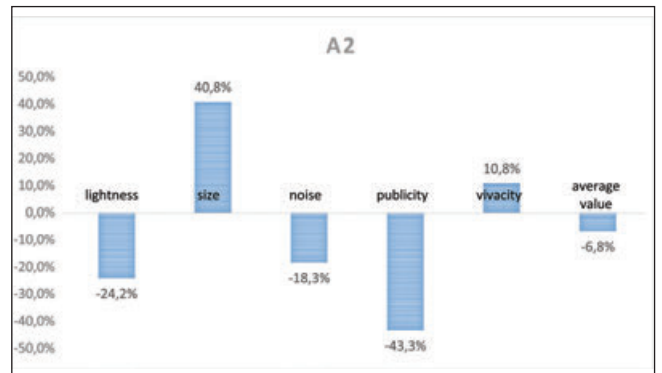
Slika 8: Percentilni rangi parametrov prebivanja osebe št. 1.
Figure 8: Percentile ranks of living parameters for person no. 1.



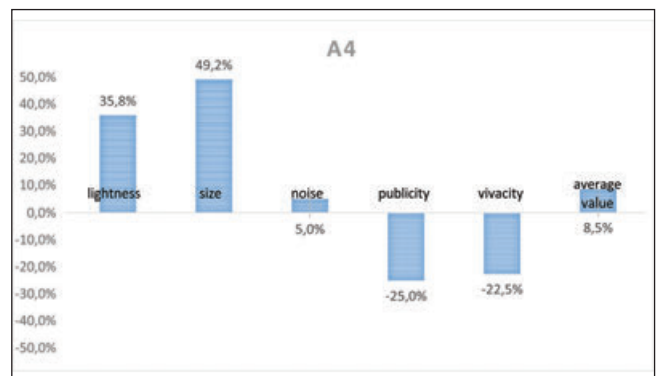
Slika 10: Percentilni rangi parametrov prebivanja osebe št. 3.
Figure 10: Percentile ranks of living parameters for person no. 3.



Slika 9: Percentilni rangi parametrov prebivanja osebe št. 2.
Figure 9: Percentile ranks of living parameters for person no. 2.



Slika 11: Percentilni rangi parametrov prebivanja osebe št. 4.
Figure 11: Percentile ranks of living parameters for person no. 4.



playing, gym, and watching TV. In the end, this makes a lot of sense. We could mistakenly place the TV set or sofa into a darker part of the apartment, which would be against the person's desires.

6. Discussion

We have shown several methods how statistical tools can be effectively used as a supplement tool in a flexible housing design, i.e. not only to learn more about the general directions that housing design should follow (correlation and average value analysis), but to be able to address the particular expectations of individual future residents (percentile ranks). It is very important that a flexible design should already limit a set of choices (e.g. types of partitions, their positions) to select from or provide a set of predefined layouts [Schneider & Till, 2007]. During the design process, the partitions can be similarly evaluated according to their provision of light, publicity, silence, and vivacity. So the right choice is more a matter of a mechanical decision than a professional one. Similarly, various layouts can be evaluated according to the overall or particular room sizes. With movable and sliding walls [ibid.], lifetime adaptability in room sizes can be achieved. As a set of choices from the book *Flexible Housing* [ibid.], we would suggest combining our design method with the following principles:

- functionally neutral rooms (allowing various room properties independent of its function),
- connections between rooms (to flexibly control lightness, privacy, and noise),
- layers and clear span (to allow lifetime changing of the partitions with different spatial parameters).

Using a simple and effective flexible design, we can combine the technological part of the process with the part on the users' side. The statistical tools are simple enough to be used in any kind of web-based platform to help potential residents to effectively and independently find the suitable future apartment.

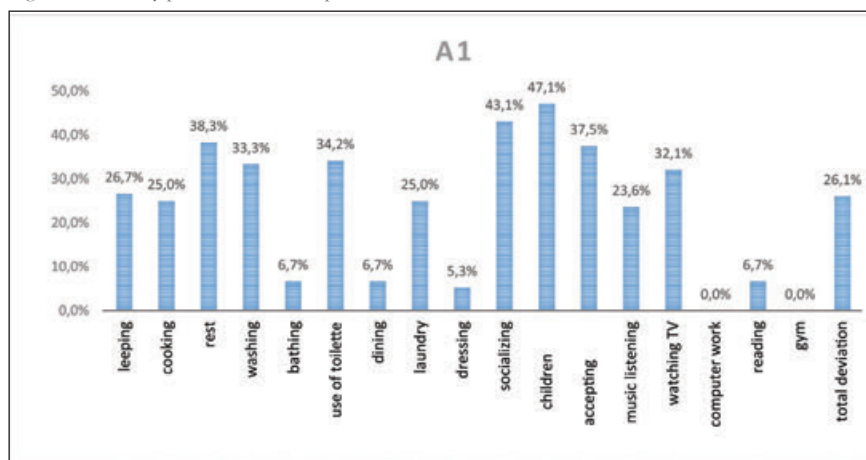
On the other hand, this research – contrary to our previous work –

proved that it is very important to use the results from the group analysis of a relatively small population with similar interests and background, i.e. the group, which is likely to define the target residents of the designed housing. If the initial population is too big or too sparse, we cannot gain enough initial directives for the overall design. We can conclude that a sample of 50 respondents is fine enough to get a relevant picture.

Smooth integration of survey results with the design method is also challenging. An interdisciplinary team of architects, designers and computer programmers could provide enough operational knowledge to make our proposed methods generally applicable.

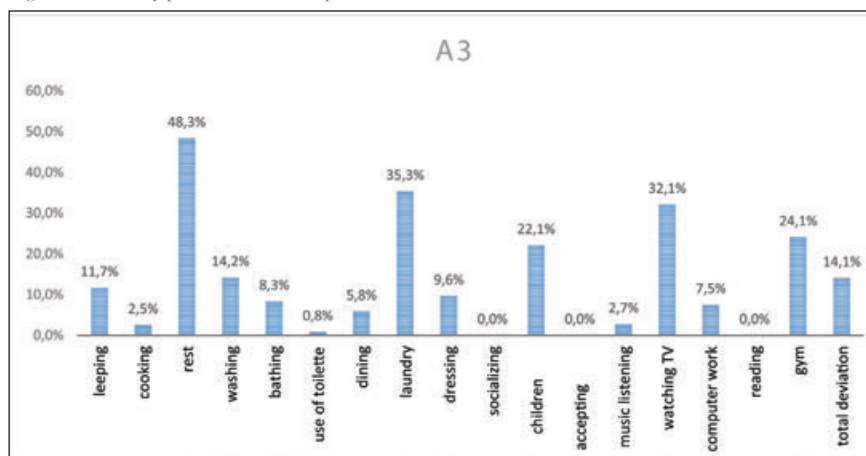
Slika 12: Percentilni rangi dejavnosti osebe št. 1.

Figure 12: Activity percentile rank for person no. 1.



Slika 13: Percentilni rangi dejavnosti osebe št. 3.

Figure 13: Activity percentile rank for person no. 3.



Bibliography

Blenkuš, M. (2003): Uporabniku in okolju prilagojeno načrtovanje stanovanjske gradnje. Univerza v Ljubljani, Fakulteta za arhitekturo, Ljubljana.

Crocker, L., & Algina, J. (1986): Introduction to classical and modern test theory. Harcourt Brace Jovanovich College Publishers, New York.

Pine, J. (1999):. Mass Customization: The New Frontier in Business Competition. Harvard Business Press., Harvard.

Schneider, T., Till, J. (2007): Flexible Housing. Routledge, New York.

Schneider, F. ed. (1994): Floor Plan Atlas, Birkhäuser Verlag, Basel.

ULRS, (2011). Ministrstvo za okolje in prostor, Pravilnik o minimalnih tehničnih zahtevah za graditev stanovanjskih stavb in stanovanj, Uradni list Republike Slovenije, 1/2011, Ljubljana.