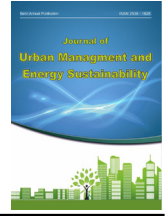


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## ORIGINAL RESEARCH PAPER

### Explanation of the research method for the analysis of bionic architecture components in housing

Amir Rezaei and Esmail Zarghami\*

Department of Architecture, Faculty of Art and Architecture, Tarbiat Dabir Shahid Rajaei University, Tehran, Iran

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#### ABSTRACT

Bionic science is a scientific field that is structurally related to the production and technical implementation of building and development processes. At the beginning of the emergence of bionic science, due to the wide range of sciences in which bionics could be effective, most of the sources were definitions, principles, and its applications have been discussed in general but there are no specific components for the field of housing with a bionic architecture approach to it. The main problem in the adaptation of bionic architecture components in the area of citizens' residence in building architecture is that according to past studies, few examples have addressed this issue. The current research method, with the aim of an exploratory and development approach, deals with the issue of bionic architecture, and by using documentary and library data, it analyzes the factors affecting the bionic quality measurement of buildings in architecture. The present research method has introduced the main components of bionic architecture in housing by using the investigation of multi-layered foundations, using interview tools and questionnaires, and analysis in Spss software, and the results indicate that the components like, curvature, balance, proportions, hierarchy, unity, open system, information processing, order, energy processing, Reaction to the environment and metabolism It provides a checklist structure that can be used to check all architectural buildings in the field of housing. In future studies, the presented research method can be examined and evaluated in a case sample.

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\*Corresponding Author:

Email: [rezaei.amir.ta@gmail.com](mailto:rezaei.amir.ta@gmail.com)

Phone: +9821 2297 0123

ORCID: <https://orcid.org/0009-0004-3754-2070>

## 1. Introduction

### 1.1. Bionic architecture

Bionics consists of two parts “Bio” and “Nic”, where “Bio” means life and “ic” suffix. It means like and like (Gérardin, 2011). According to Nachtigall, the German word bionic is from the English word Bionics is derived from the combination of two words biology (biology) and technology (technology) (Nachtigall 2013). Modeling nature has a long history, as a clear example. This approach can be used in modeling palm trees and lotus flowers in the construction of columns in temples and palaces observed Also, the art of ancient peoples often had a symbolic aspect, which was a direct perception of nature at first, there have been, and over time, simplified forms of nature in the form of ritual paintings and motifs on pottery have been used (Salingaros, 2003). Although modeling nature has a long history, the first scientific work in this field was done by Leonardo da Vinci. He studied the movement mechanism. Birds tried to build a flying car while flying. Although he did not succeed in this task, his efforts can be considered the first example of a bionic encounter. In connection with the subject of bionics, various opinions have been presented by thinkers, but almost those who work in this field emphasize that bionics is a science that does not try to copy, but it should Generate ideas for new designs that improve existing models. (Yowell & Oklahoma, 2011) In this regard, according to Jack E. Steele (2008), bionics is a science based on living systems, or they have the characteristics of living systems or are similar to living systems (Gérardin, 2011). Nachtigal (2013) In the definition of bionic science, it is a scientific field that is structurally related to the production and technical implementation of building and development processes. The principles of biological systems are related, introduces (Nachtigall 2013). Also, Gruber the concept of inspiration from He considers nature generally equivalent to the word “bionics” in German and the word “biomimetic” in English and calls it Knowledge of robotics and replacement and optimization of living components, such as tissue, body parts, and organs by prescription introduces their mechanics (Gruber, 2011). Among the sciences related to the subject of bionics is

biochemistry, He mentioned biomechanics, biophysics, biotechnology, etc. Germans are the leaders in designs based on a “Bio” base they usually use the term bionic (Yowell & Oklahoma, 2011). In general, three levels can be. He defined biological among animals and plants that today’s knowledge can imitate in the following three formats:

- 1- Imitation of natural production methods
- 2- Imitation of mechanisms in nature
- 3- Investigating and analyzing the collective and social behaviors of living things such as the collective migration of birds (Karami, 2011).

Sarikaya (1994) divided the science of bionics into two parts “biomimetics” meaning the correct understanding of biological systems and their productivity of them in artificial cases using technology and “Bio application” meaning using new methods like genetic engineering, which divides producing class of new materials (Sarikaya, 1994). The term biomimetic is widely used in England. In Webster’s dictionary, this word is study. The formation, and structure of biologically produced materials and samples, as well as the biological process and mechanism in particular It is mentioned to make similar products with artificial mechanisms (Yowell & Oklahoma, 2011).

This can be deduced that the concept of bionics is considered a comprehensive topic, of which biomimetics is one of them Its sub-branches. Therefore, in a general sense, the topic of inspiration from nature and modeling it can be understood as bionic explained. Bionics as an interdisciplinary science uses the concepts of natural sciences and engineering and the skills of the fields It combines biology, physics, chemistry, mechanics, architecture, etc. You can get the bionic soul and essence summed up in the slogan “Nature has already done it” (Bain and Paul, 2009). In bionic design, researchers, suggest two methods. These methods include the problem-oriented method and the solution-oriented method. Furthermore, in two methods, bionics has three main levels organism, behavior, and ecosystem (Peters, 2011). It is related to a specific plant or animal organism and may lead to imitation of the whole or part of it. The level of behavior is based on the interpretation of aspects

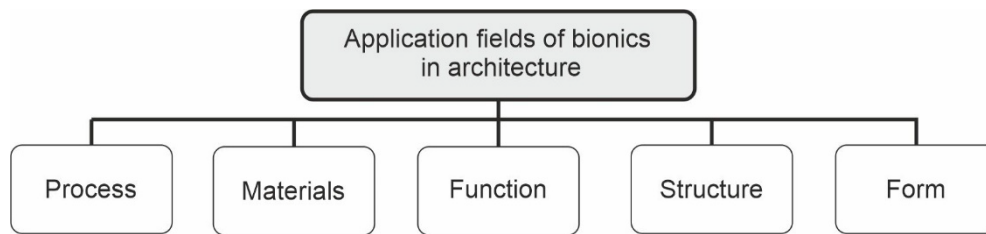


Figure 1: Application fields of bionic in architecture

of how an organism behaves or its relationship with the larger part; and surface ecosystem includes imitation of whole ecosystems and common rules between them (Zari, 2007). (Fig. 1)

Modeling nature at the three levels of organism, behavior, and ecosystem is done now this issue is raised, in which parts of architecture can imitation of nature occur and appear to better understand this issue, and the opinions of some thinkers in this field are examined. Wan Ting Chiu and Shang Chia (2009) discuss bionic design theories, and bionic application areas in architecture in four parts, they introduce pattern, structure, function, and material (Wan-Ting & Shang-Chia, 2009). Javier Senosiain (2013) in the book “Bio Architecture” is one of the essential aspects in the design of nature and man-made designs. He knows performance and emphasizes the intrinsic connection between performance and form. In addition to his performance of the space in nature, the structure in It also refers to nature and form in nature. Therefore, according to him, the areas of application of bionics in architecture are four parts Function space, structure, and shape (Senosiain, 2013). According to Mahmoudinjad (2013)’s opinion in many sources, the Bionic form has been introduced as the field of application of bionics in architecture, so the scope of this application can be seen. He observed from North America to Greece and from Egypt and Iran to India and China (Mahmoudinejad, 2013). Also, five fields of form, structure, function, materials, and process are introduced as areas of bionic application in architecture (Zari, 2007). Among the different architectural approaches in the last few decades, the relationship with nature is one of the most important topics which has caused

different theories. Some have paid attention to nature from the point of view of wisdom and logic, some Theories deal with the experience of form and space, while others explain the relationship between form and function by examining natural forms. They pay and some others follow the apparent connection with natural elements such as water, rain, sky, etc. Among the different approaches, the two approaches “Sustainability” and “Bionic” as the most important approaches to architectural communication and nature, about which various theories have been expressed. A sustainability approach in the 70s and a response to environmental degradation were formed. The purpose of this approach, which has three environmental, social, and economic aspects is to meet the current needs of man without jeopardizing his future needs. (Brundtland 1985) Sustainable architectural thinking is an attempt to harmonize architecture with the environment to reduce the negative effects on it. It is managing consumption and responding to human social needs (Weingaertner and Moberg 2014).

### 1.2. Research Background

At the beginning of the emergence of bionic science, due to the wide range of sciences in which bionics could be effective, most of the sources were definitions, principles, and their applications have been discussed in general. Also, the authors of these sources are mainly biologists. Nachtigall (1997) can be considered one of the first to study, research, and publish works in the field of modern bionic science. He has collected a large collection of bionic examples and has put a lot of effort into organizing this issue (Nachtigall, 1997). In his later work, he collaborated with

Goran Pohl, who has an architectural education, to use science. Bionic has also made efforts in design and construction (Nachtigall, 2005; Pohl and Nachtigall, 2015) Janine Benyus (1997) “ Biomimicry Institute “, founder in America, author of several books in the field of bionic science and creator. The word is biomimicry. According to him, biomimicry is not just imitating nature, but nature is a teacher, and a standard for measurement is innovation (Benyus, 1997). In this regard, Alena Iouguina's (2013), master's thesis, with a comparative analytical look at research and investigation of the use of three terms in the common field of nature and design, namely bionics, biomimetic, and biomimicry. It has been discussed in the past and present (Iouguina, 2013). In many bionic sources, form is introduced as the first source of inspiration from nature. In this regard, Aldersey-Williams & Feuerstein (2003) in their books have a series of structures with natural forms and shapes that have been introduced and depicted in their time and place (Aldersey-Williams, 2003; Feuerstein, 2002) But over time, various scientists used this science to solve human problems. including city planners and architects who have researched and published works in this field including Christopher Alexander, Petra Gruber, Ilaria Mazzoleni, and Michael Pawlyn named. Alexander explains the nature of order and living structures in urban planning and architecture. also, He enumerates the fundamental characteristics of nature that create life (Alexander, 2010). Gruber (2011) also in his doctoral thesis himself at the Technical University of Vienna explains the relationship between bionic science and human settlements and interprets the criteria of life in that step takes away (Gruber, 2011) but by presenting examples of how to use bionics in one of the components explains human settlements (building shell) (Mazzolini, 2013). Pawlyn (1971) also introduces bionic design methods including problem-oriented and solution-oriented and provides examples of its application in architecture (Pawlyn, 1971). In line with this issue, Portoghesi & Oliver (2007) in their books are a collection of images of native human habitats and construction traditions around the world. (Portuguese, 2000, Oliver, 2007) Wan Ting and Shan Chia (2009) in a

research study and analyze the literature related to bionics in the Eastern and Western world. He examines the background of bionics, they analyze the issues in the field of bionics and the field of biology. Philosophical thoughts, design, and architecture are also examined (Wan-Ting & Shang-Chia, 2009). and Ahmadi says about the relationship between architecture and nature that the formalistic and apparent perceptions of nature will lead to an empty architecture; And the presence of the spirit of nature in architecture is to promote and manifest it will end Therefore, instead of appearance, one should look for meaning and the principles that cause growth, evolution, and life Organisms are in the environment, searched (Doan, 2022). Murphy (2020) in another study investigated Natural structures used to model them in architecture. Therefore, it introduces natural forms and finally, he analyzes the designs that have been successful in using natural forms (Murphy, 2020). Based on the research conducted in the field of the relationship between architecture and nature in the contemporary era, with the dimming of the semantic dimension of Man, the provision of material needs from nature is emphasized, while in the past, architecture followed the order of nature and according to concepts such as multi-functionality, it has provided human needs. In this age of communication architecture and nature have been investigated with different approaches. For this reason, most foreign studies emphasize more on content analysis and expression of the structure of analytical models, and generally do not introduce a direct research method.

## **2. Materials and Methods**

The research method is one of the most basic components of determining the validity and value of the research work, which is a set of rules, tools, and reliable and systematic answers to investigate facts, discover unknowns, and reach solutions. Problems are referred to. One of the characteristics that determine the validity of research work is the method and tools used in the research. By choosing the research method, a researcher can adopt a method or a method to help him to reach possible answers as accurately and easily as possible. With these interpretations,

the foundation of science production is research. On the other hand, research is the main platform for a deep and accurate understanding of facts, thinking, and thought. In the meantime, choosing the correct and appropriate method with the research objectives and using tools aligned with it is important in the effectiveness and accuracy of the results of any research, therefore, in the current research, it is also an effort to choose according to the research fields and the requirements of the research. The appropriate method of research and selection of effective tools to advance the process should be discussed

### 2.1. Methodology

Choosing the housing sector of the construction industry for research means following some characteristics, which should be recognized as the main sector and compatible with bionic architecture significantly, and should be recognized with a large number of large companies at the end of the housing development cycle. It is desirable to interact. The main method is to send questionnaires to professors, consultants, and builders in the housing sector. To analyze their answers, in terms of their understanding of the effects of inspiration and modeling of bionic components, they are effective factors in physical and mental comfort. However, to increase the accuracy of the research, the revision was done by focusing more on the opinion of first-class experts and by arranging interviews and receiving more information about their supply chain. To carry out this research, a combination of descriptive research and content analysis was used. Descriptive research describes and interprets what is and pays attention to existing conditions and relationships, common beliefs, and current processes. Descriptive research includes collecting information to test hypotheses or answer questions related to the current state of the subject being studied. Descriptive information is collected through a questionnaire, interview, or observation. The method of content analysis also depends on the careful study of sources and documents. This method is used to analyze the obvious content (surface meaning of the text) as well as the deeper layers of hidden meanings in the documents.

### 2.2. Reason for using the method

[Robson \(1993\)](#) describes three types of social research strategies; Experiments, to measure the effects of manipulation of one variable on other factors, case studies, to develop accurate and intensive knowledge about a case or a small number of cases, and polls, which can be used as a set of information in a standard form from It is an individual description of a known mass that usually deals with a relatively small amount of data. According to the previous explanations, the most appropriate research strategy was investigated for descriptive knowledge. There are two main types of measurement, questionnaire, and interview. The method chosen for this research is a combination of both methods. In the first stage, both questionnaires were sent to professors, contractors, and consultants, and then interviews were conducted with some experts to receive more information. Some of the advantages and disadvantages of the pre-interview questionnaire are:

### 2.3. Benefits

The use of a simple method to study attitudes, motivations, beliefs, and values, and makes it possible to collect general information. Also, this is a low-cost method that takes less time, especially if there are time constraints ([Robson, 2002](#)).

### 2.4. Disadvantages

Usually, the speed of reaction is slow, and there may be misunderstandings or ambiguities during completion, and lead to irrelevant answers that need more or new information to clarify the answers ([Bryman, 2004](#)). And finally, the data may be affected by audience characteristics such as lack of seriousness or response based on desirability instead of facts ([Robson, 2002](#)). Normally, the important characteristic of polling is that the study itself is not a sample, but the average perception of the society is extracted from it as a result. For this research, the sample companies can be a clear indicator of the current methods. However, it is important to mention that the studied sample cannot be a comprehensive representative.



### 2.5. Compilation of questionnaires

Questionnaires are usually designed with a set of features that help increase the response rate of the audience. Closed questions are used instead of open questions to reduce the variety of answers, facilitate interpretation and coding, and avoid misunderstandings with clear questions with a set of possible answers. In the cover letter, the purpose of this survey and its confidentiality were explained to create a more realistic view of the respondents. Although there is no reason to prove the increase in response as stated.

### 2.6. Test method

Since the purpose of the research is to identify the effective components of bionic architecture to improve comfort in housing, ten professors who have a history of studies and design in the field of the keywords of the thesis are part of the statistical population. Interviews were selected. On the other hand, because traces of the use of bionic patterns can be seen in contemporary technological architectural works, also to make the statistical population comprehensive and increase the confidence of the interview, 20 professional architects of the country and 10 companies of consulting engineers who have works They are urban scale, they were selected as the second and third part of the statistical population of the interview.

In the interview, five open and identical questions were asked to each of the experts, and the summary of their opinion was recorded in the registration form, and at the end of the interview, it was approved and signed by them. A sample of the interview sheet and the statistical population of the interview are given in the appendices section of the thesis.

### 2.7. Interviews

As discussed, there are provisions for interviews (step 8 of Figure 6-3). The main correction was that instead of comparing the results of two questionnaires, the results obtained based on the answers depended on the financial circulation and the strength of their supply chain. The interview was designed as a structured interview to standardize the answers and draw

conclusions in the analysis of the questionnaire.

### 2.8. Statistical Society

The set of units that share at least one characteristic defines a statistical community (Khaki, 2014). The statistical population of this research includes two sections of first and second-grade experts.

### 2.9. Population

The construction industry includes a wide range of companies including construction contractors, mining companies, product manufacturers, builder investors, specialized services, etc. It is estimated that the number of companies related to the construction industry in Iran is about 35,000 companies, of which about 15,000 are in the profession of contracting and consulting, and the rest are in the role of suppliers.

First-class experts: including designers and university graduates who are well-informed about the research topic, who, according to the conducted research, have more expertise and knowledge than other managers of their level. The number of people available in this community who cooperated for the present research under the title of first-class experts is 20 people.

Second-level experts: including companies and rank 1 consultant from the country's Program and Budget Vice-Chancellor who have ISO 14000 certification, with at least 25 years of experience and experience in designing important residential complexes in the country. Following the investigations that took place in this field and by examining the records of the active companies, it was found that the number of these experts is 10 people.

### 2.10. Sampling

An example is an introduction to society and it is a set of signs that is selected from a part, a group, or a larger society so that this set represents the qualities and characteristics of that part, group, or larger society (Khaki, 2014). In this research, sampling has been done in two parts. The first part of sampling is to select first-class experts, and the sampling in this part is theoretical or judgmental. Theoretical or judgmental sampling is the selection of a part of the society whose

members are determined based on the judgment of the researcher. It should be noted that in this section, the number of samples is the same as the number of (available) community members (10 people). Table 3-5 shows the distribution of these samples. (Tab. 1)

The second part of sampling is about the selection of experts for the questionnaires. The statistical population of this department is the sum of first and second-level experts, so for sampling in this case, a combination of theoretical sampling and simple stratification was used. Simple stratified sampling is a type of sampling in which the main population structure consists of different strata and classes, and in which each stratum or class has common features and attributes. In this way, the first-class experts are the same 10 people and were selected based on theoretical sampling, and the other samples were selected based on simple random sampling. In this section, the samples (contracting and consulting companies) of the companies with the first rank from the Office of the Program and Budget Organization of the country with and with certificates and after that are stratified based on the amount of experience (at least 25 years) of the said company and based on that from The members of this community, the companies that

first had the largest number of projects and volume of transactions and then had the most experience in this field, were selected as samples. , and for the suppliers, first production and distribution at the country level, production of key items and having the ISO 14000 certificate, and then including the supply chain were identified as vital factors to achieve this goal. The formula used to determine the number of samples for questionnaires:

$$n = \frac{Z^2 N \sigma^2}{(N-1)e^2 + Z^2 \sigma^2}$$

n= Sample ads.

N= 35/51 Number of Society members

$\sigma = 0 / 5$  standard deviation

$$n = \frac{(1.96)^2 * N * (0.5)^2}{(95-1) * (0.1)^2 + (1.96)^2 * (0.5)^2} \cong 33 \quad 25$$

In this way, based on the formula, the number of samples was calculated to be 33 for companies and 25 for suppliers, taking into account the confidence factor, the number of 75 questionnaires was distributed according to the composition of Table 6-3, and finally, the questionnaire was answered. (Tab 2)

Table 1: How to distribute the samples of the first part (first-class experts)

| First-class experts | University professors | Companies | Total |
|---------------------|-----------------------|-----------|-------|
| 10                  | 10                    | 10        | 40    |

Table 2: how the samples of the second part are distributed

| Desired section       | The number of distributed questionnaires | The number of answered questionnaires |
|-----------------------|--|---------------------------------------|
| Consulting company    | 10                                       | 8                                     |
| University professors | 10                                       | 9                                     |
| First-class experts   | 20                                       | 16                                    |
| Total                 | 40                                       | 31                                    |

Table 3: Main outputs from the mean test

| Main outputs | t                     | df                 | sig     | mean          | St.d               |
|--------------|-----------------------|--------------------|---------|---------------|--------------------|
|              | Sampling distribution | Degrees of freedom | meaning | Average value | standard deviation |

Table 4: functional components of bionic architecture in housing

| Bionic components            | Application in housing   | Description  |
|------------------------------|--|--|
| Curvature                    | Changing the shape of natural hard materials into pleasant and human forms   | Reducing the solidity of objects strengthens the sense of relaxation in residents  |
|                              | Non-linear and curved architecture (induces a state of weightlessness and a sense of softness in a person (Mahdovinejad, 2011))  | Creating comfortable and intimate treasures to meet and chat and be alone  |
|                              | Compliance with the central order  | Symmetry and order in the design convey a sense of peace to the residents  |
| Balance and balance          | the active balance between natural activities (harmony)  | Harmony in the activities creates a structured understanding in the human being and thus induces a conscious process in the resident that gives a sense of security according to the human thought system. |
| Proportions                  | Observing the harmony between the length, width, and height of the space with use and harmony in the space   | Compliance with golden proportions in the building   |
|                              | Human scale and flat and low spaces (not inducing a sense of inferiority), not designing the floors in a vertical direction  | Height causes a feeling of fear and height causes a feeling of suffocation   |
| Unity                        | Use of organic and primary mineral materials (Placement of elements simply together)   | Creating the opportunity for different experiences through the variety of spaces (creating a sense of curiosity), the flexibility of the space   |
|                              | Building in a natural landscape and view from the building to the surrounding natural landscapes   | The building is in sync with a natural process and its design form is following the natural organic structure  |
|                              | The spread of forms on a horizontal plane to understand more space and pay attention to the horizon line (horizontal planes aligned on the ground) (attention to the horizon line) | The ability to understand and read the space creates a sense of peace  |
| Conceptual                   | Inducing a special meaning (use of ideas and concepts in design to induce this feeling) symbols and signs  | Metaphysical concepts bring peace to the residents   |
| Openness (open system)       | Suitable light during the day, sufficient light in spaces at night for rest and personal and social interactions (soft light) - electro-optical and electrochromic layers          | The flexibility of the building leads to the comfort of the residents, an increase in members, and no need to move   |
|                              | A person's connection with nature through openings   | The architecture of open (yard) and semi-open (porch) spaces, the presence of nature in three primary and secondary aspects  |
|                              | Moving from the outer world to the inner world and completely dependent on the inner world   | The variety of variables within the environment  |
|                              | Semi-permeable membranes (adaptive permeability), temporary materials  | The building's access to the outside space in emergencies and independence in energy consumption   |
| Limitation of space and time | Permanent and temporary settlements, settlement construction scale   | The scale of the settlements is determined according to comfort, security, and the need for infrastructure   |
|                              | Recycling of materials   | Considering the limited resources, recycling brings comfort to the residents   |
| Order                        | Minimize ambiguity   | An order and order of the environment accelerates its perception and at the same time gives it a stretch that encourages people to explore it.   |
|                              | Physical or geometric order based on the science of mathematics  | Map scales - compliance with aesthetic principles  |



Table 4: functional components of bionic architecture in housing

|                             |  |  |
|-----------------------------|--|--|
|                             | Hierarchy  | Separation of public and private space, passing through secondary space to reach private space and continuity of space, ease of understanding space              |
|                             | Functional order   | Order in the spatial hierarchy, the order in the construction stages increases the final quality   |
| Energy processing           | Ecological design, energy control  | Conservation of thermal energy   |
|                             | Climate design, using sensors to avoid unexpected reactions                | Housing design suitable for the region's climate, movement of parts or the whole settlement, and the use of self-healing materials                               |
| Reaction to the environment | Stimulate the senses   | Stimulation of the five senses by natural elements such as water, colored and aromatic plants, the smell of soil, etc.   |
|                             | Attendance and intervention in design and construction project application | Interview and questionnaire of space users about relaxing factors, recognition of the user's moods and needs, and increasing the individual's sense of belonging |
|                             | Reaction to the environment  | Use of smart materials   |
| Metabolism                  | Control of comfort parameters  | Implementation of an intelligent building management system (BMS)  |

2.11. Validity of the questionnaire

The meaning of validity is that the measurement tool can measure the desired characteristic and is a suitable tool for measurement (Khaki, 2014). In this research, taking into account that the questionnaires used have been approved by respected professors and, on the other hand, taking into account that the items mentioned in the questionnaire are items that have already been approved by first-class experts, it means that these questionnaires have validity. (credibility) are necessary to measure the subject under investigation.

2.12. Reliability of the questionnaire

The reliability of a measuring device mainly refers to the accuracy of its results. In addition, reliability also refers to the reliability, stability, and repeatability of test results (Momoni and Qayyomi, 2016). Cronbach's alpha method was used to determine the reliability of the second questionnaire. Based on this test, if the alpha coefficient is more than 0.7, then the test (questionnaire) has acceptable reliability. The value of the alpha coefficient for this questionnaire was calculated according to the answers received using spss software and this value is equal to 0.972. Therefore, according to

the results, the current questionnaire has the necessary reliability.

2.13. Analysis of questionnaire data

In this research, the hypothesis test (mean) method was used to analyze the answers of experts regarding the questionnaire. This test can be used to analyze the mean of a single variable and multiple variables (this test is also known as a t-test). In this test, it is determined whether the average of the sample (the average of the respondents' opinions) has a significant difference from the average of the society or not. If the answer is positive, it means that the result (mean value) is meaningful and reliable, and if the answer is negative, it means that this value is not significant and cannot be relied on. In this research, spss software was used to perform this test, and the main outputs of this test include the values that are mentioned in Tab. 3.

t is a type of sampling distribution that provides a special distribution for each sample. By increasing the value of df (degree of freedom), this distribution has more dispersion and will be closer to the normal distribution. The degree of freedom is also a function of the number of samples, which means that this value also increases with the increase in

Table 5: Architectural building recognition checklist with bionic architectural components

|   |         | Bionic pattern                    |                        |          |                             |
|---|---------|-----------------------------------|------------------------|----------|-----------------------------|
|   |         | Alive                             |                        | Not live |                             |
| Non-mineral                                 |         | mineral                           | herbal                 |          | animal                      |
| Using the components of bionic architecture |         |                                   |                        |          |                             |
| Appearance components                       |         | Functional and process components |                        |          |                             |
| curvature                                   | balance | proportions                       | hierarchy              | unity    | open system                 |
|   |         |                                   | information processing | order    | energy processing           |
|   |         |                                   |                        |          | Reaction to the environment |
|   |         |                                   |                        |          | metabolism                  |
| Idea and plan                               |         |                                   |                        |          |                             |
| Plan  |         |                                   |                        |          |                             |
| Structure                                   |         |                                   |                        |          |                             |
| Facade                                      |         |                                   |                        |          |                             |
| Materials                                   |         |                                   |                        |          |                             |
| Volume                                      |         |                                   |                        |          |                             |
| Open and semi-open space                    |         |                                   |                        |          |                             |
| Space function                              |         |                                   |                        |          |                             |

the number of samples. The significance level is influenced by the values of  $t$  and  $df$  and its value based on these values as the main output of this test determines whether the value of mean (mean of the samples) is significant or not. Determining this significance is based on the level of confidence they consider for the test. Usually, the confidence level (significance) in this test is considered equal to 95%, and in the present research, this value is also considered equal to 95%. Therefore, in the conditions where the significance value ( $\text{sig}$ ) is less than 0.05, it can be said that the average value of experts' opinions about the relevant question is significant, and in the conditions when this value is greater than 0.05, it means that this average value is not significant. It should be noted that in the questionnaires that were completed by the respondents, the respondents were asked to specify the severity of the impact of the event against each of the related factors with the options that were quantified as below and entered in spss software<sup>1</sup>.

### 3. Findings and Discussion

#### 3.1. Testing methods of using bionic architectural components in the housing

At the end of the previous chapter, based on studies and objective observations, and analysis of examples of contemporary housing architecture, we compiled the methods of using the functional components of the bionic architecture. As mentioned, in the research process, the researcher prepared the following table as the functional components of bionic architecture in housing. (Tab. 4)

Now, to prove the validity of our claim about the quantity and quality of these methods, we are testing them. For this purpose, we refer to experts in this field, and through a scientific interview plan, we share with them the theoretical foundations and methods of using bionic architectural components and seek their expert opinions. In the following, we will investigate the

<sup>1</sup> For 5-choice questions: 5=strongly agree, 4=agree, 3=neutral, 2=disagree, 1=strongly disagree, 5=very important, 4=important, 3=neutral, 2=little importance, 1=very little importance

For 4-choice questions: 0=not related to the company's field of expertise, 1=low, 2=moderate, 3=high

For 3-choice questions: 01 = low, 2 = medium, 3 = high, 01 = no need, 2 = optional, 3 = mandatory

correctness of our claim by citing and analyzing these opinions.

#### 3.2. Test method

Since the purpose of the research is to explain the theoretical foundations of architectural technology based on natural systems, ten university professors who have research experience in the keywords of the thesis (bionic architecture, comfort in housing) were selected as part of the statistical population of the interview. On the other hand, because traces of the use of natural systems can be seen in contemporary technological architectural works, as well as to make the statistical population comprehensive and increase the confidence of the interview, ten of the country's professional architects who have urban-scale works, As the second part, they were selected from the statistical population of the interview. In the interview, four identical questions were asked to each of the experts, and the summary of their opinion was recorded in the registration form, and at the end of the interview, it was approved and signed by them. A sample of the interview sheet and the statistical population of the interview are given in the appendices section of the thesis.

### 4. Results and Conclusion

In this section, the questions raised in the interview are presented and then the abstract of the answers of some experts (statistical community) is given and analyzed to get their opinion about the question and finally to confirm or reject the issue raised in the question.

- Can the use of bionic architecture be effective in realizing (physical and mental comfort)?
- In your opinion, what are the methods of using the functional components of bionic architecture in housing?
- According to the functional components of bionic architecture (...), which component do you consider more effective in providing comfort in housing?
- Name other components that can be effective in providing physical and mental comfort in housing.

Based on this, the component model of bionic architecture can be explained by recognizing its structure in housing and especially the

architecture of residential buildings as follows:

Dividing the organic model into two types of living and non-living, based on natural origin, using the method of using the authors in the form of keywords, curvature, balance, proportions, hierarchy, unity, open system, information processing, order, energy processing, Reaction to the environment and metabolism. (Tab. 5)

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