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RESEARCH ARTICLE

THE INFLUENCE OF NANOTECHNOLOGY ON ARCHITECTURAL DESIGN: AN APPROACH

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ABSTRACT

This paper gives a summarized part of a PhD research, which deals with the real impact that nanotechnology and nanotechnology materials can have on all the phases of Architectural Design. The relations between our main research variables, i.e. Nanotechnology materials and Architectural design, have been approached through two main strategies. The first is through the hidden knowledge that is the "tacit" knowledge, which is highly personal and lies behind the architectural works or other forms of Art. The second strategy concerns the type of knowledge known as "explicit" knowledge, which is formal and systematic. This paper presents a broad idea of the attempt to follow the second strategy in order to test the hypothesis of the dissertation. The hypothesis states that "nanotechnology materials have a determinant impact on all the phases of Architectural design". A special survey made via an especially customized questionnaire in order to see how a homogenous sample of people evaluate the degree of influence that nanotechnology materials have on all the phases of Architectural design, namely design, construction, life-cycle and cost of an architectural artifact e.g. a building. The research methodology is briefly presented and the results are equivalently analyzed.

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INTRODUCTION

It has been suggested that people can respond to perceptual cues embodied within architectural works. These are related to the construction of built environment, the types and forms of buildings as well as to their broader context. These responses can be measured through descriptive tools and appropriate scales. The main problem of our research is to develop a tool to collect data of this king, discussing the relevant methodological issues concerning two basic aspects, i.e. sampling and scale construction. This research, being unique in its content and nature, has given great attention not only to the aspects above, but also to the aspects of experiment design and implementation, data analysis and results interpretation. Another important issue is the proper statistics for analyzing this type of data obtained by the field research. During the resent years a vague theory was covering the architectural atmosphere. That theory was stating that building materials impose a considerable effect on architectural design. There was plenty of evidence which could support a theory that may be explaining the above suspected relationship. Today this is partly accepted by the relevant scientific knowledge on the field of Architecture. Last decade important scientific progress has been done on the field of nanotechnology and nanomaterials. So much progress to be able to reach the proposal that nanotechnology materials are proven to have enormous potential to influence architectural design and construction to a greater extend. The present paper deals with the search of that relationship, in order to show that this relation is real and definitive. Furthermore, it is trying to detect how and to what stages of architectural design nanotechnology and nanomaterials with their great potential characteristics affect the whole process of architectural design. Nanotechnology on one hand is the technology that deals with mater at nanoscale. What architectural design is, on the other hand, it is conceived here as a set of four descriptive and interconnected phases that are: (a) the design phase which starts with the idea, goes through the plans and the designs and leads to form the executive plan, (b) the construction phase which starts up with the implementation plans, surveying, controlling and finishing all the works, and ends with the concession to the users, (c) the life-cycle of the structure (e.g. building) which starts with the concession of the project and the launch of its use, the everyday operation, services and maintenance and ends with its final demolition, and (d) the total cost, which contains the planning, construction, operational and maintenance costs.

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Technology in Architecture

A positive effect of technology in architecture is the computer aided design and the creation of 3D models (CAD, modelling, 3D rendering, and 3D printing). The next step is realized by the introduction of genetic architecture in combination with nanotechnology. Computer design techniques strengthen the interdisciplinary relationship between architecture and other sciences. Also, new building techniques and construction methods have rendered project implementation easier and more efficient. New organic forms inspired by nature can now be digitally produced and constructed.

Nanotechnology

Nanotechnology is the design, characterization, production and application of forms, mechanisms and systems through controlled manipulation of shapes and dimensions at nanoscale that produces forms and systems with at least one improved or new property (NanoWerk, 2014).

The development of nanomaterials will bring benefits to society (GENNESYS, 2009):

- Research on nanomaterials has major influence on health, information technology, energy and other areas, where much economic benefit lies on commercialization of new technologies,
- Regarding energy efficiency, the research of nanomaterials will lead to new materials that will lead to more efficient operation of power plants and enable the development of new energy systems based on renewable sources,
- Development of nanomaterials will cause reduction of negative environmental impact from the production process of materials (less pollutants) and form the presence of waste (efficient and enhanced materials don't need to be replaced often).

Nanotechnology is a very diverse area and ranges from conventional material-matter manipulation to completely new approaches. It is a rapidly developing field with numerous current and potential applications in various other fields. Many possibilities that nanotechnology can offer, if combined together, can promote architectural creation and construction. Innovative new nanomaterials and nanosensors have already been giving the architect a new tool palette. Properties such as self-cleaning, self-repair and self-assembly have promoted the performance of architectural projects. Nowadays, nanotechnology has already been applied to construction materials such as concrete (stronger, greater durability, easy assembly), steel (stronger) and glass (self-cleaning). The use of nanotechnology in the material industry leads to efficient use of raw materials and also reduction of negative environmental effects which emerge from material production processes (less pollutant emissions, less raw materials used) (UNEP, 2010).

Architecture

Architecture in simple words means the science that translates human needs into functional three dimensional structures, the art of synthesis that is the effective way of combining elements to create more complex forms. Architectural evolution has brought up new demands in performance and energy efficiency of structures and sustainability of buildings. The term Architecture refers to both the process and the product of planning, designing, and constructing buildings and other structures. Architectural works are often perceived as cultural symbols and/or works of art. Civilizations are often identified with their surviving architectural achievements. The word "architect" comes from the combination of two Greek words «αρχή» and «τέκτων» which means "master constructor". By others, architecture means the origin of arts and crafts. Architecture encapsulates the style, design and construction of buildings and other physical structures, the knowledge of art, science, technology and humanity, the design activity of the architect, from the macro-level (urban design, landscape architecture) to the micro-level (construction details and furniture). This science deals with planning, designing and constructing form, space and ambience to reflect functional, technical, social, environmental and aesthetic considerations. It requires the creative manipulation and coordination of materials, technology, light and shadow. Often, conflicting requirements must be resolved. The practice of Architecture also encompasses the pragmatic aspects of realizing buildings and structures, including scheduling, cost estimation and construction administration. Documentation produced by architects, typically drawings, plans and technical specifications, defines the structure and/or behaviour of a building or other kind of system that is to be or has been constructed. Thus, nanotechnology employed in architecture leads to "Nanoarchitecture", a promising endeavour.

Architectural Design – A concept

Looking for the relationship between the above mentioned two basic variables, this study took a double and coordinated research initiative. First the research used the type of knowledge called tacit. Tacit knowledge is highly personal, which in the words of the philosopher M.Polanyi is stated as "we can know more than we can tell". This type of knowledge is deeply rooted in action and in individual work. As far as architecture is concerned tacit knowledge can be hidden within great Architectural projects, designs or methods. Secondly, the other road towards the target is the use of the other type of knowledge called "explicit" knowledge (Nonaka, 2000). Explicit knowledge uses formal and systematic research methods, like those used in scientific research. This strategy uses monitoring and experimental results to prove any hypothesis in question.

Researching the relationships between Nanotechnology Materials and Architectural Design

The above coordinating method is based on the work of philosophers M. Polanyi, I. Nonaka, T. Kuhn and K. Popper on knowledge which says in similar ways that "human knowledge is much more than what the language can deliver". Therefore human beings, who had too much knowledge, should discover several ways apart from the ordinary languages to express it. Architecture and Arts are ways to express that knowledge. In that case we can approach it through the study of those important works of great architects and we can be able to find evidence to support our hypothesis. The explicit knowledge, on the othern hand, can be easily communicated and shared. It is this type of knowledge that comes through a process of empirical study using scientific emperiments to collect evidence. To collect this knowledge we have designed and performed a field research using social research techniques and a specially constructed questionnaire. The data collected via

those techniques, as they are analyzed, have supported the initial hypothesis that nanotechnology materials affect in a considerable degree the Architectural design.

Formatting the research tool for experimental Data Collection

In order to obtain the experimental data to support our hypothesis a series of experiments has been planned and implemented. Analyzing our main variables to treat experimentally, we divided them into two main categories, i.e.:

1. Familiarity variables, which examine how familiar are the subjects with the architectural design and all its stages, as well as with nanotechnology and nanomaterials. At the same time, these variables show how much of the tacit knowledge the subjects will be able to designate within the works of great architects.
2. Evaluative variables, which mark the relationship between nanotechnology materials on one hand and architectural design on the other.

Through data gathering and their quantification, and therefore their statistical analysis, we have been able to examine the hypothesized relationship. The above variables formed an ad hoc constructed questionnaire which was given to a special group of subjects. The subjects had to evaluate the relation in question. The procedure of questionnaire design, scale construction, population sampling and experiment performance was as follows:

a. Questionnaire design and evaluation factor construction: the whole work of constucting the proper factors for measurement and designing the questionnaire to collect the evaluative responses out of the subjets followed the methodology for questionnaire construction containing specially designed five-step interval evaluation scales. This was relevant because our research aim was to measure the value of a number of factors which are not randomly selected.

On the contrary, they were eliminated from an ad hoc deductive process of elicitation. Many researchers borrow a number of standard scales ready for proper use, in their attempt to construct questionnaires that correspond to the needs and goals of specific research. In this occasion the expected results could be open to critisism and vulnerable in some way, on the basis of using terms or attributes within their scales which are not relevant to the case.

- On the other hand, many authors, supporting the personal construct theory (Kelly, 1955) express the view that every person in constructing their architectural (or built) environment they use terms, discriptive adjectives or concepts that are not common to everyone. These intra-individual differences relate to their personality and their past experience within the built environment. To overcome this kind of skepticism many research workers use a deductive process for eliciting the proper terms and having in mind the scope of their research they construct the appropriate scales, relevant to their case. Our study, in its process to construct the appropriate evaluation factors, combines the above two methods. It takes factors from the two semantic universes i.e. the semantic area of people studying architecture and construction and the area of the researcher with their particular scope, goals and objectives. The questionnaire consists of four basic evaluative categories each of which contains several evaluation dimensions. In particular, the factor “design” is analyzed into 18 scales-dimensions, the factor “construction” into 17 the factor “life-cycle” into 10 scales-dimensions and the factor “overall costs” into 10 scales-dimensions. By the evaluation of the mentioned dimensions the relationship between the variables was measured.

b. First questions: due to the specificity of the subject it was necessary in the introduction of the questionnaire to clarify the term "Nanotechnology" and "Architectural Design". The term "Nanotechnology" includes nanotechnology materials, hybrid materials and enhanced traditional materials. The term "architecture" includes four key factors: design in architectural scale, manufacturing mainly buildings (residential architecture), life cycle of buildings (duration, maintenance, operation) and overall costs. Before starting the evaluating process, the subjects were called to respond to a series of nine (9) questions which measured the degree of their familiarity with the four (4) main factors. This was considered to be a necessary step to secure fidelity of the data. It is a sort of controlling the degree of credibility of experimental results to be obtained. Moreover, this checks the fact that the subjects possessed the knowledge about what nanotechnology is and how it can serve the purpose of expressing Architecture to an adequate degree.

c. Measuring scales: There are several methodologies for creating measuring scales with most known the Likert, Guttman and Turstone. The Likert-type scale is the easiest to create and most widespread in social and pedagogical research. Its aim is to measure attitudes or opinions of the subjects on a set of questions which represent the problem under study. These responses reflect the scale of agreement or disagreement on a certain statement. By the concentration of a tank of axiological and descriptive terms, we have reached to a number of 20 to 30 finalists that correspond to the criteria, firstly by choosing those with the higher frequency and secondly those that show a relativity with the aims and objectives of the research. After obtaining the prevailing terms (dimensions of factors) we proceeded to construct evaluation criteria in the form of the 5 intermediate points scale (Likert).

Field Research

Methodological Issues of Sampling

The problem of sampling in this sort of research is very important (Brislin, 1973). There are many ways of selecting the sampling group (Craik, 2002). It is done either by some “apriori” criteria or by starting with direct response process to the environment and developing a typology proper to the scope of the study. The nature of population of this study’s sample relates to the validity of the results. Therefore, issues concerning the nature of population are very important. From the point of view of the study’s purpose and its administration a sample of people around 50 individuals is the ideal number, which covers all the requirements. As far as the nature of the sample is concerned, this was formed by two groups of people

with the following characteristics. The one is from students from the School of Architecture and the other is from young architects who are practicing Architecture. All of those are active in the same field of science and around the same area (Thessaloniki). The fact that are studying or practicing architecture means that the individuals share a lot of similarities. This gives the sample a great degree of homogeneity and correspondence. The groups that are formed out of horizontal sections of the community give a great degree of similarity. Other than that, characteristics such as age, personality, sex, socio-economic status, education etc. can be very easily controlled. Finally, it should be noted that in those kinds of research random samples are not recommended. This is because a great validity and precision is needed, so horizontal cross section samples are the ideal for the purpose of the current research.

Implementation of the Experiment

So far the design of the research process was presented. Here the implementation of the field research is summarized. The designed questionnaire consists of the introduction, explaining the nature and purpose of the investigation, and five (5) parts. The first part includes the familiartiy questions and the following four parts include the four principal factors analyzed into subsequent dimensions that need to be evaluated. This research eventually involved two groups of subjects. The first consisted of thirty (30) students of Architecture in the corresponding Department of the School of Engineering at the Aristotle University of Thessaloniki, and the second of thirty (20) young professionals of architecture working in the architectural and constructional field. The performance of the questionnaires was done in two ways. Students engaged in the experiment were given a printed form of the questionnaire and professionals were offered the digital version. Students were asked to complete the notebook before or after their course. After they were given some necessary clarifications concerning the purposes of the survey and how to finalize it, the subjects of the research completed the notebook with plenty of time. The second group of subjects answered the digital version, which was provided to them in a form of a link[1]. The electronic collection of data was equally efficient and easy. The results of the responses gathered in this way, significantly strengthened the experimental data. The whole procedure worked very well and the experimental data were easily obtained. Any data obtained via the two methods was characterized by considerable uniformity, percision and validity. Therefore, they are considered statistically acceptable.

Analysis of the Experimental Results and Data Interpretations

All the results obtained by the experiment are shown in figures 1 to 5 in graphical form. Figure 1 shows the results from the first part of the questionnaire. The results refer to the familiarity data of the subjects. In the figures all the relevant statistical numerical analysis is given in the form of a graph that represents the average. The same results are shown in the form of evaluative curves in Figures 2 to 5. The familiarity results, represented by figure 1, lead to the conclusion that the response data from the subjects are not evaluative responses from lay people but from people with a good knowledge of the area in question. Both groups reached a level of 3.037, which means that the subjects were well informed about the items they called to evaluate. The second part (Figure 2) shows the evaluative data of the first factor “design”. The results from all 18 dimensions are concentrated in the graph and give the numerical result of 3.467, which means that nanotechnology and nanomaterials have a good influence on design. In the third part the results of figure 3 are analyzed in the same way. These correspond to how nanotechnology materials influence the factor “construction”. From the evaluative response data an all the dimensions of the factor the degree of influence comes to 3.600 which means that nanotechnology has much influence on the factor construction. Explaining the argument further it is clearly shown from the data nanotechnology materials exercise a considerable influence on all the phases of constructing an architectural project (e.g. building). The most important element here is taken to be the use of new and smart materials that can successfully correspond to progressive requirements needed in materializing modern architectural forms. Fourth part deals with the experimental results obtained via the ten dimensions of the factor “life cycle” of the architectural work. The relevant data and their statistical treatment are shown in figure 4. From the evaluation response data is clearly shown that nanotechnology performance gives great possibilities to make the life of a building longer. In lasting longer, the maintenance needs of a building are eliminated. The degree of influence of nanotechnology on the third factor is 3.532, which means that nanotechnology and nanomaterials exercise much influence on the “life cycle” of a building.

As far as the last factor “overall cost” is concerned, the results from the evaluative data are shown in figure 5. Experimental data here show that nanotechnology and the use of nanomaterials tend to minimize running cost as well as the cost of maintenance and repair of a building.

Brief presentation of the questionnaire is shown in the following table:

Table 1. This table includes the questions and possible answers per part – factor of the research

Part 1: Familiarity questions	How much do you: 1.know about Nanotechnology and Nanomaterials Science 2.know about Nanotechnology applications 3.know about Nanomaterials and their use 4.believe that Nanotechnology can affect other fields of science 5.believe that Nanotechnology can affect the quality of human life 6.believe that Nanotechnology can affect the environment 7.know about Architectural Science 8.consider that Architecture affects the quality of human life 9.consider that the application of Nanotechnology can affect the Architectural activity	The possible answers: none (1) little (2) enough (3) much (4) very much (5)[1] and N/A

Continue…….

[1] To perform the online survey a platform by Survey Monkey was used (https://www.surveymonkey.com/), with the help of which the questionnaire was distributed by hyperlink to subjects and through social networking.

Part 2: Factor "Design"	How much do you believe the application of Nanotechnology can:	The possible answers:
	1.lead to flexible design	
	2.enable the creation of new forms	
	3.help to exploit the new possibilities of architecture	not at all (1)
	4.lead to diversity of forms in architecture	a little (2)
	5.offer the ability to create unique forms	enough (3)
	6.allow the creation of uniform spaces	much (4)
	7.help to elevatie the style of architecture	very much (5)
	8.lead to the unity of architectural expression	
	9.allow the creation of comfortable spaces	and N/A
	10.lead to overcoming problems in design	
	11.tend towards the logical organization of space	
	12.facilitate the exploitation of natural light	
	13.enhance the comfort of the internal environment	
	14.make it easy to implement advanced design	
	15.facilitate the use of different deisgn methods and software	
	16.broaden the way and the field of thinking of architects	
	17.lead to the realization of compact construction	
	18.tend towards the creation of new relationships between men – buildings – environment	
Part 3: Factor "Construction"	How much do you believe the application of Nanotechnology can:	The possible answers:
	1.lead to flexible constructions	
	2.make it easier to build new forms	
	3.lead to the feasibility of new designing ideas	not at all (1)
	4.lead to the exploitation of new ways and possibilities in manufacturing building projects	a little (2)
	5.provide greater safety during construction	enough (3)
	6.facilitate better organization in the manufacturing process	much (4)
	7.provide greater speed of construction	very much (5)
	8.offer the possibility of bridging larger spans	
	9.provide easy use of construction tools	and N/A
	10.facilitate better organization and service of the production lines	
	11.provide easy upward extensions	
	12.facilitate the application of paint	
	13.lead to efficient insulation and waterproofing of buildings	
	14.facilitate efficient heating and air conditioning	
	15.allow the creation and maintenance of stable indoor microclimate condition	
	16.ensure hygiene and safety	
	17.permit the use of innovative materials	
Part 4: Factor "Life-cycle"	How much do you believe the application of Nanotechnology can:	The possible answers:
	1.ensure respect to and less damage of the environment	
	2.enable the hosting of new and alternative uses, that can prolong life-cycle	
	3.provide better security in buildings throughout their existence	not at all (1)
	4.provide a possibility to easily reorganize and change the use of buildings	a little (2)
	5.offer greater ease of operation and of serving many needs	enough (3)
	6.maintain a stable internat environment characterized by safety and hygiene	much (4)
	7.result in a longer duration of protective coatings	very much (5)
	8.provide undiminished and stable exploitation of daylight	
	9.lead to extending the duration of the existence of the structure	and N/A
	10.lead to the minimization of the required maintenance tasks	
Part 5: Factor "Cost"	How much do you believe the application of Nanotechnology can:	The possible answers:
	1.lead to greater speed of construction of the building	
	2.offer longer life span of the building	
	3.reduce design costs	not at all (1)
	4.reduce manufacturing costs	a little (2)
	5.minimize operation and maintenance costs	enough (3)
	6.have the effect of reducing the time needed in each phase of the project	much (4)
	7.lead to successful handling of changes because of time saving	very much (5)
	8.increase the commercial value of buildings	
	9.create and preserve stable quality of the construction project	and N/A
	10.lead to the use of materials with a larger initial cost, which is proven less per unit of time in comparison to conventional materials due to larger lifespan	

Part I: Nanotechnology and Architectural Design – Familiarity Questions

How much do you:

1. know about Nanotechnology and Nanomaterials Science
2. know about Nanotechnology applications
3. know about Nanomaterials and their use
4. believe that Nanotechnology can affect other fields of science
5. believe that Nanotechnology can affect the quality of human life
6. believe that Nanotechnology can affect the environment
7. know about Architectural Science
8. consider that Architecture affects the quality of human life
9. consider that the application of Nanotechnology can affect the Architectural activity

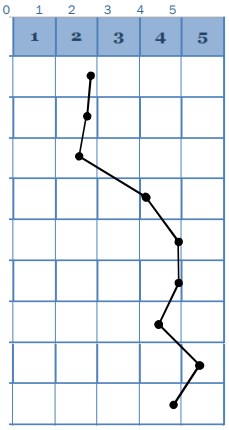

Figure 1. The results of the first part of the social research are represented in graphical form.

Part II: Design

The application of Nanotechnology can:

1. lead to flexible design
2. enable the creation of new forms
3. help to exploit the new possibilities of architecture
4. lead to diversity of forms in architecture
5. offer the ability to create unique forms
6. allow the creation of uniform spaces
7. help to elevatie the style of architecture
8. lead to the unity of architectural expression
9. allow the creation of comfortable spaces
10. lead to overcoming problems in design
11. tend towards the logical organization of space
12. facilitate the exploitation of natural light
13. enhance the comfort of the internal environment
14. make it easy to implement advanced design
15. facilitate the use of different deisgn methods and software
16. broaden the way and the field of thinking of architects
17. lead to the realization of compact construction
18. tend towards the creation of new relationships between men – buildings – environment

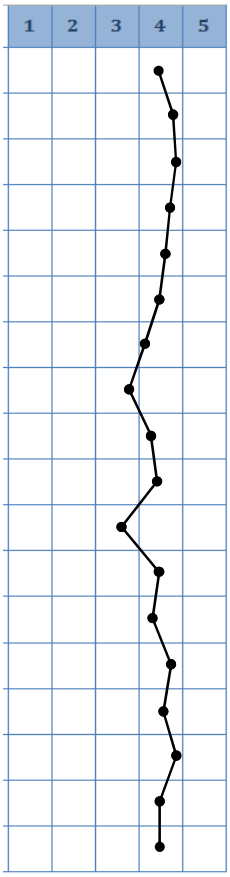

Figure 2. The results of the second part of the social research are represented.

Part III: Construction

The application of Nanotechnology can:

1. lead to flexible constructions
2. make it easier to build new forms
3. lead to the feasibility of new designing ideas
4. lead to the exploitation of new ways and possibilities in manufacturing building projects
5. provide greater safety during construction
6. facilitate better organization in the manufacturing process
7. provide greater speed of construction
8. offer the possibility of bridging larger spans
9. provide easy use of construction tools
10. facilitate better organization and service of the production lines
11. provide easy upward extensions
12. facilitate the application of paint
13. lead to efficient insulation and waterproofing of buildings
14. facilitate efficient heating and air conditioning
15. allow the creation and maintenance of stable indoor microclimate condition
16. ensure hygiene and safety
17. permit the use of innovative materials

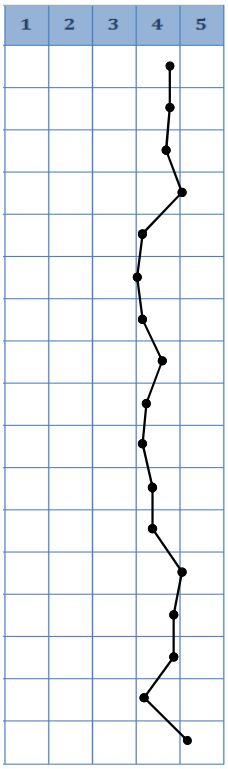

Figure 3. The graph results of the third part are represented.

Part IV: Life-cycle

The application of Nanotechnology can:

1. ensure respect to and less damage of the environment
2. enable the hosting of new and alternative uses, that can prolong life-cycle
3. provide better security in buildings throughout their existence
4. provide a possibility to easily reorganize and change the use of buildings
5. offer greater ease of operation and of serving many needs
6. maintain a stable internat environment characterized by safety and hygiene
7. result in a longer duration of protective coatings
8. provide undiminished and stable exploitation of daylight
9. lead to extending the duration of the existence of the structure
10. lead to the minimization of the required maintenance tasks

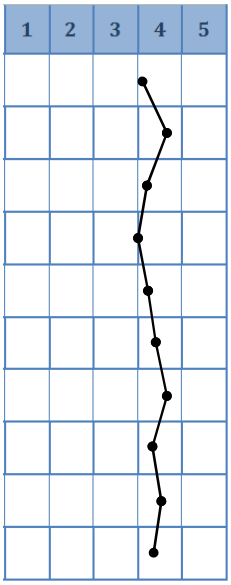

Figure 4. The graph results of the fourth part are represented.

Part V: Cost

The application of Nanotechnology can:

1. lead to greater speed of construction of the building
2. offer longer life span of the building
3. reduce design costs
4. reduce manufacturing costs
5. minimize operating and maintenance costs
6. have the effect of reducing the time needed in each phase of the project
7. lead to successful handling of changes because of time saving
8. increase the commercial value of buildings
9. create and preserve stable quality of the construction project
10. lead to the use of materials with a larger initial cost, which is proven

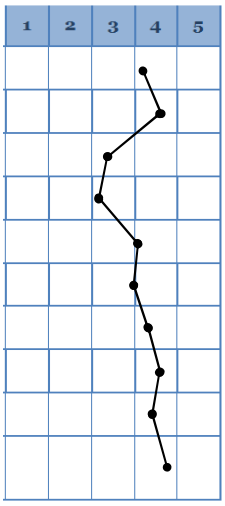

Figure 5. The graph results of the fifth part are represented.

Influence of Nanotechnology on Architectural Creation

1. On design in architectural scale
2. On building construction
3. On life-cycle of buildings
4. On overall construction and operational costs

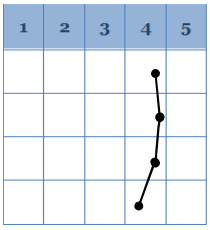

Figure 6. Cumulative data of each of the four factors are shown in graph form.

Factor "cost" relates to the factor construction which under the influence of nanotechnology minimizes the cost by shortening the construction time. Analyzing the cost curve in figure 5 we see that it is moving through the area of much, which means that nanotechnology materials when implementing within architectural design exercise much influence on the factor "overall cost". Finally, from the analysis of cumulative data and calculation of the total degree of influence of the independent variable (nanotechnology) on the dependent (architectural design) is 3.464. This is interpreted as a significant level of influence of nanotechnology on architectural design. Therefore the analyzed data support the study's main hypothesis. We can also assume that nanotechnology has the potential of changing considerably the means of expressing the architectural ideas and progressively formulating the new language of nanoarchitecture.

Conclusion

The experimental results and the knowledge, which derived from the implementation of a unique methodology for reaching the truth behind the hypothesis and the performed strategy of

the approach through the "tacit" and "explicit" knowledge, could be used to facilitate architectural theory. Having found the relation between materials (i.e. means of expressing ideas and new ways of dealing with them) and architectural design (i.e. design, construction, life-cycle and cost), we proceeded to a social research with the selection of a centralized group of people in order to investigate the level of influence between two variables, an independent and a dependent, nanotechnology and architectural design respectively. In the comparison of the analytical profiles, we see a miraculous homeotropic between both subjects and variables (factor and corresponding dimensions). This is reasonable since it has to do with the selection of the sample and the statistical processing of data in reply. This demonstrates the significance of such data themselves, but also the compatibility of the methods of statistical analysis. It should be noted, however, that the moderate impact of nanotechnology (adequate knowledge about the object and its capabilities from those involved in research), which is observed in the entire population, shows homogeneous data, possibly leading to more moderate responses (the average is 3-4 and not clear at 4-5).

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Table 2. This table presents the cumulative data of the 1rst part of the questionnaire

PART I: EVALUATION DATA OF FAMILIARITY QUESTIONS							
	DIMENSION						
	1	2	3	4	5	6	7
SUBJECT 1	2	2	2	4	3	4	4
2	2	2	1	3	5	5	3
3	3	2	2	3	4	4	3
4	1	2	2	4	4	5	5
5	2	2	1	4	2	5	4
6	1	1	1	3	2	4	3
7	2	2	1	4	3	5	4
8	2	2	2	5	3	4	5
9	1	1	1	3	2	5	3
10	1	1	1	5	2	5	5
11	2	2	2	4	4	4	3
12	2	2	1	5	3	5	4
13	2	1	1	4	5	5	4
14	2	2	2	4	3	5	4
15	2	3	2	5	3	5	5
16	3	2	1	5	3	5	4
17	2	2	2	3	3	4	3
18	2	1	1	4	3	5	3
19	2	2	1	3	2	5	3
20	1	1	1	3	2	5	3
21	2	2	1	5	4	5	4
22	1	1	1	4	3	5	4
23	1	1	1	3	3	4	4
24	1	2	1	3	3	4	4
25	2	2	1	4	3	5	5
26	1	1	1	3	3	4	3
27	1	1	1	4	4	5	5
28	1	1	1	3	2	4	4
29	2	2	1	3	2	4	3
30	2	1	1	4	2	5	4
31	2	2	1	4	3	4	3
32	2	2	1	2	3	4	2
33	2	2	1	4	3	4	4
34	3	3	3	5	4	5	5
35	2	3	3	4	5	0	4
36	3	2	2	5	4	5	4
37	2	2	2	4	4	4	4
38	2	2	2	5	3	5	5
39	4	3	4	5	5	5	5
40	2	2	2	4	4	5	3
41	2	3	3	5	5	5	4
42	2	2	2	4	5	4	4
43	2	2	3	4	5	5	4
44	2	2	2	4	5	5	4
45	2	1	1	5	4	4	5
46	2	1	2	4	4	4	4
47	2	2	2	5	5	5	3
48	2	2	2	5	5	5	5
49	2	2	2	4	5	5	5
50	2	2	2	3	5	5	3
SUM	95	91	80	199	176	227	195
MEDIAN	2	2	1	4	3	5	4
AVERAGE	1,90	1,82	1,60	3,98	3,52	4,54	3,90
ST.DEVIATION	0,61	0,60	0,73	0,80	1,05	0,81	0,79
VARIANCE	0,38	0,35	0,53	0,63	1,11	0,66	0,62

Table 3. This table presents the cumulative data of the 2nd part of the questionnaire

PART II: EVALUATION DATA OF THE 18 DIMENSIONS (FACTOR "DESIGN")																		
	DIMENSION																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SUBJECT 1	4	3	4	4	4	3	4	3	3	4	3	4	3	5	4	3	4	4
2	3	3	4	4	4	3	2	3	4	1	3	5	3	3	2	4	1	5
3	3	3	3	2	3	3	4	2	4	4	3	4	3	4	3	4	2	3
4	2	4	3	4	1	2	2	4	3	2	1	3	2	2	2	3	1	2
5	3	4	3	2	3	3	4	4	3	3	3	3	3	4	4	5	4	4
6	3	3	4	3	3	3	3	3	3	0	0	0	3	3	0	4	3	2
7	3	3	3	3	4	3	3	4	3	3	4	3	0	3	4	4	3	4
8	4	5	5	5	5	5	4	2	5	4	4	5	5	4	5	5	5	5
9	2	3	3	3	4	3	3	2	3	4	4	4	3	4	3	3	4	3
10	4	2	5	4	3	5	4	5	5	4	1	5	5	4	5	5	5	5
11	4	4	3	4	3	3	3	2	3	3	2	4	3	3	4	2	3	2
12	4	5	5	4	4	4	3	4	4	4	3	4	4	5	5	4	5	4
13	3	4	5	5	4	4	2	2	2	3	2	2	2	4	2	4	3	4
14	4	4	4	4	5	4	5	4	5	3	4	4	5	3	3	5	4	4
15	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	2	3
16	4	4	4	3	3	4	3	2	4	4	2	3	3	4	4	5	3	4
17	3	4	3	3	3	4	3	2	4	4	3	3	4	3	4	3	3	4
18	4	5	5	5	5	3	4	1	1	2	1	4	1	5	5	4	5	1
19	3	3	3	4	4	2	4	1	2	3	2	2	2	4	3	2	3	3
20	3	4	3	3	4	3	3	2	3	3	2	4	3	4	3	2	3	2
21	3	3	5	5	3	5	3	3	4	4	3	5	5	5	3	5	5	3
22	4	5	4	4	5	3	3	2	2	4	3	4	4	4	3	5	4	5
23	4	5	3	4	5	4	4	2	3	4	3	2	4	5	4	5	4	3
24	3	4	4	3	3	2	2	3	3	4	2	3	4	4	3	3	3	4
25	3	4	4	5	4	3	3	3	3	4	3	3	4	5	3	5	3	4
26	3	4	3	4	3	2	1	2	2	3	2	3	2	3	3	3	2	4
27	3	4	5	5	2	4	1	1	2	5	4	3	2	1	5	5	3	5
28	4	4	4	4	3	3	3	3	4	4	4	4	4	5	5	5	4	4
29	4	4	3	4	4	5	3	2	3	4	3	4	4	4	3	5	3	4
30	4	3	5	3	3	5	3	3	5	5	3	3	4	5	3	4	3	3
31	3	3	3	4	3	4	4	2	3	3	3	4	2	4	4	4	3	3
32	3	3	3	3	3	2	3	3	2	3	2	2	2	3	3	4	3	3
33	3	3	5	5	4	4	4	4	4	3	3	5	5	4	4	5	5	5
34	5	5	5	5	5	5	5	5	5	4	4	4	4	5	5	5	4	4
35	3	4	4	3	4	4	3	3	3	3	3	3	3	3	3	3	3	0
36	3	5	5	4	5	3	4	2	2	5	3	5	3	5	5	4	4	5
37	4	3	3	3	4	3	3	3	3	2	2	3	3	3	3	3	3	3
38	4	4	4	4	4	5	4	3	3	4	3	4	3	4	4	4	4	4
39	5	4	4	4	5	5	4	5	5	4	5	4	5	5	5	4	4	4
40	3	4	4	4	4	4	4	3	3	4	3	5	3	4	4	3	5	2
41	4	4	5	3	3	3	4	4	4	4	4	5	4	5	4	5	5	4
42	4	4	3	3	3	2	3	2	3	2	2	3	2	2	3	4	3	3
43	2	1	1	1	2	2	1	3	4	2	1	0	3	2	2	2	2	2
44	4	2	4	2	0	2	2	0	3	4	2	3	2	4	4	4	4	2
45	4	5	4	4	5	4	5	4	4	3	3	4	4	4	5	3	3	3
46	4	4	4	3	3	3	3	4	5	4	3	4	4	3	3	3	3	4
47	2	3	3	3	4	2	3	2	2	2	2	3	4	3	4	3	4	4
48	3	5	5	5	5	3	1	3	3	4	1	3	3	5	5	4	4	3
49	4	3	5	3	3	4	3	3	3	2	1	2	2	2	2	3	3	4
50	4	4	4	4	4	4	3	3	3	4	3	3	3	4	4	4	4	4
SUM	174	188	195	185	182	173	160	142	167	170	134	174	163	191	181	195	173	173
MEDIAN	3,5	4	4	4	4	3	3	3	3	4	3	4	3	4	4	4	3	4
AVERAGE	3,48	3,76	3,9	3,7	3,64	3,46	3,2	2,84	3,34	3,4	2,68	3,48	3,26	3,82	3,62	3,9	3,46	3,46
ST.DEVIATION	0,74	0,89	0,91	0,93	1,06	0,99	1,01	1,11	1	1,03	1,04	1,15	1,12	1	1,09	0,95	0,99	1,09
VARIANCE	0,54	0,8	0,83	0,87	1,13	0,99	1,02	1,24	1	1,06	1,08	1,32	1,26	1,01	1,18	0,91	0,99	1,19

Table 4. This table presents the cumulative data of the 3rd part of the questionnaire

PART III: EVALUATION DATA OF THE 17 DIMENSIONS (FACTOR "CONSTRUCTION")																		
	DIMENSION																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SUBJECT	1	4	4	5	4	4	4	3	4	3	4	4	3	4	4	4	3	5
	2	1	5	2	3	3	4	1	3	3	3	4	4	4	4	3	2	5
	3	2	3	4	2	3	4	5	3	3	3	2	3	3	3	4	3	2
	4	2	2	2	3	2	3	1	2	3	2	1	2	3	2	3	1	2
	5	3	3	4	4	4	2	3	4	4	4	4	3	4	5	4	4	4
	6	4	3	3	4	4	3	3	4	3	4	3	4	4	3	3	3	3
	7	4	4	4	4	3	3	3	4	3	4	3	3	3	3	3	3	4
	8	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5
	9	3	3	3	4	4	2	3	4	4	4	3	4	4	4	4	4	4
	10	5	5	5	5	4	4	5	5	3	3	4	5	5	5	5	4	5
	11	4	3	3	3	2	2	3	4	3	2	3	2	4	3	3	2	4
	12	5	5	4	5	3	3	3	4	2	3	4	4	5	5	5	3	5
	13	2	4	2	4	2	3	3	4	3	2	4	3	3	3	2	2	4
	14	5	5	4	4	5	4	5	5	4	4	5	5	5	5	5	4	5
	15	5	5	5	5	3	3	3	4	5	3	5	5	5	5	5	5	5
	16	5	4	4	5	3	3	4	4	4	3	4	4	4	4	4	4	5
	17	4	3	2	4	3	2	3	3	3	3	4	4	5	4	4	3	3
	18	5	5	4	5	5	5	5	2	5	5	5	2	2	3	3	2	4
	19	4	4	4	4	3	3	3	3	4	3	3	2	3	3	3	2	3
	20	3	3	4	4	2	2	4	3	3	3	4	3	3	3	4	3	4
	21	4	4	4	4	5	4	4	4	3	5	3	5	5	5	5	5	4
	22	4	4	5	4	3	3	2	4	4	3	5	3	4	4	3	3	5
	23	4	4	5	5	2	2	3	5	1	4	4	2	3	3	4	3	5
	24	4	3	3	4	4	3	3	3	4	3	3	2	4	4	4	4	5
	25	5	4	5	4	3	4	3	2	3	3	3	4	3	4	4	3	5
	26	4	4	3	5	3	3	1	2	3	2	2	2	3	3	2	1	5
	27	5	4	3	3	3	4	3	3	3	5	3	3	3	4	2	3	5
	28	4	4	4	4	5	5	4	2	3	4	3	5	5	5	5	5	5
	29	3	4	4	3	3	3	4	4	3	4	4	3	4	4	3	2	3
	30	5	3	5	5	3	3	3	3	5	3	3	3	5	5	5	3	5
	31	3	3	2	4	3	2	3	3	3	3	2	4	4	4	4	3	4
	32	2	4	4	4	3	4	5	4	4	2	3	3	3	2	3	2	4
	33	4	4	5	4	3	4	4	4	4	3	4	4	5	5	5	4	5
	34	4	4	5	5	0	0	0	3	0	4	5	0	5	5	5	4	5
	35	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	4
	36	4	4	5	4	3	3	2	3	2	3	3	4	5	5	5	0	0
	37	3	3	3	3	2	2	3	3	2	2	3	3	3	3	3	2	3
	38	4	4	4	4	4	2	4	4	2	3	4	4	5	5	5	5	5
	39	5	4	4	5	4	4	4	5	5	4	4	4	5	5	5	4	4
	40	4	4	4	4	0	0	0	5	5	0	3	5	5	5	5	5	5
	41	4	4	4	5	4	4	4	4	4	4	3	5	5	4	4	5	5
	42	4	3	4	3	3	3	3	3	4	4	4	3	3	3	4	3	3
	43	3	4	3	3	1	1	2	3	1	1	2	3	5	5	4	3	2
	44	4	2	2	5	2	3	4	5	3	3	3	5	5	2	5	2	5
	45	3	5	3	3	3	3	2	5	3	3	3	3	5	2	3	4	3
	46	4	5	3	5	5	4	5	5	5	4	0	3	5	5	5	3	4
	47	4	3	4	5	5	5	5	4	4	3	4	4	4	4	3	4	5
	48	4	4	4	5	5	5	3	4	3	5	3	4	4	4	3	4	5
	49	3	4	3	4	4	1	3	4	3	2	3	2	5	3	4	3	5
	50	3	3	3	3	3	3	3	4	3	3	4	3	3	3	3	3	5
SUM		190	191	187	204	162	153	160	184	165	162	170	171	204	194	194	160	209
MEDIAN		4	4	4	4	3	3	3	4	3	3	3	3	4	4	4	3	5
AVERAGE		3,8	3,82	3,74	4,08	3,24	3,06	3,2	3,68	3,3	3,24	3,4	3,42	4,08	3,88	3,88	3,2	4,18
ST.DEVIATION		0,95	0,77	0,94	0,78	1,19	1,15	1,23	0,89	1,07	1,02	1,01	1,09	0,9	0,98	0,94	1,14	1,1
VARIANCE		0,9	0,6	0,89	0,61	1,41	1,32	1,51	0,79	1,15	1,04	1,02	1,19	0,81	0,96	0,88	1,31	1,21

Table 5. This table presents the cumulative data of the 4th part of the questionnaire

PART IV: EVALUATION DATA OF THE 10 DIMENSIONS (FACTOR "LIFE-CYCLE")										
	DIMENSION									
SUBJECT	1	2	3	4	5	6	7	8	9	10
1	4	4	3	4	5	4	4	3	4	5
2	2	3	2	3	3	3	3	2	4	3
3	3	3	4	3	3	2	3	3	5	3
4	0	0	0	0	0	0	0	0	0	0
5	4	4	4	3	4	4	4	4	4	4
6	3	2	3	3	3	3	3	2	3	2
7	3	4	4	3	3	3	4	3	3	3
8	5	5	5	4	5	5	5	5	5	3
9	4	4	4	3	3	3	4	4	4	4
10	2	5	3	1	5	3	5	5	4	5
11	3	2	3	2	3	3	3	3	3	2
12	3	4	3	4	3	4	3	4	4	3
13	3	5	3	3	5	2	2	2	5	5
14	4	5	5	4	4	5	5	5	5	4
15	5	5	3	4	5	5	4	5	5	5
16	3	4	3	5	5	4	4	4	5	3
17	4	3	3	3	2	4	4	3	3	4
18	1	4	4	2	5	2	1	3	4	1
19	2	3	2	2	3	3	3	2	3	2
20	3	3	3	3	3	3	4	3	4	3
21	3	3	4	4	3	4	4	3	4	4
22	5	4	4	4	4	5	5	3	4	4
23	2	4	4	2	4	3	4	4	2	3
24	3	4	4	2	3	4	4	4	4	4
25	3	4	3	3	3	3	3	2	3	4
26	3	3	2	2	3	3	3	3	3	2
27	5	5	4	4	3	3	4	3	2	3
28	5	5	5	4	3	5	5	4	4	3
29	2	2	3	3	3	4	4	3	4	4
30	3	5	4	3	5	5	3	3	3	3
31	3	3	2	4	3	4	4	4	3	2
32	3	3	3	3	4	3	3	2	3	3
33	5	5	4	4	4	5	4	5	5	4
34	4	5	4	4	5	5	5	4	4	4
35	3	3	3	3	3	3	3	3	3	3
36	3	4	4	3	2	3	4	5	5	4
37	2	3	2	2	2	3	3	3	3	3
38	4	5	3	3	3	4	5	5	5	5
39	5	5	5	5	5	4	4	5	5	5
40	3	4	4	4	4	4	5	5	5	4
41	4	5	5	3	4	5	5	4	5	5
42	4	3	3	3	3	4	3	3	3	3
43	3	1	3	1	2	3	5	3	3	4
44	3	5	4	3	4	3	5	5	5	5
45	5	5	3	5	4	3	4	3	3	4
46	0	0	4	4	3	5	4	4	3	4
47	5	4	4	5	4	4	4	4	4	4
48	4	4	2	2	3	3	3	3	2	3
49	3	4	3	2	3	3	5	3	4	4
50	4	4	4	4	4	3	3	4	4	4
SUM	167	188	172	160	172	180	189	176	187	175
MEDIAN	3	4	3,5	3	3	4	4	3	4	4
AVERAGE	3,34	3,76	3,44	3,2	3,44	3,6	3,78	3,52	3,74	3,5
ST.DEVIATION	1,32	1,25	0,99	1,09	1,09	1,09	1	1,09	1,05	1,07
VARIANCE	1,74	1,57	0,99	1,18	1,19	1,18	0,99	1,19	1,09	1,15

Table 6. This table presents the cumulative data of the 5th part of the questionnaire

PART V: EVALUATION DATA OF THE 10 DIMENSIONS (FACTOR "COST")										
	DIMENSION									
SUBJECT	1	2	3	4	5	6	7	8	9	10
1	4	4	3	3	4	4	4	4	5	5
2	2	3	3	3	4	3	2	4	2	4
3	3	3	4	3	3	2	3	3	3	4
4	0	0	0	0	0	0	0	0	0	0
5	4	4	4	3	3	4	4	3	4	5
6	3	3	2	3	2	3	2	3	3	3
7	4	4	3	3	3	3	3	4	4	3
8	5	5	3	2	3	5	4	5	5	5
9	4	4	4	3	3	4	3	5	5	5
10	3	5	3	3	2	3	3	5	5	5
11	3	3	3	3	2	2	3	4	3	2
12	3	4	3	3	2	2	3	4	2	4
13	5	4	3	3	2	2	4	2	3	3
14	4	5	4	4	4	5	4	4	4	5
15	5	5	5	5	5	3	5	5	4	4
16	4	4	3	4	4	4	3	3	3	3
17	3	3	2	3	3	3	3	3	4	3
18	5	4	4	2	4	4	3	3	3	4
19	3	3	4	3	2	3	3	4	3	3
20	4	3	4	4	4	4	3	4	3	3
21	4	4	4	4	4	3	3	4	3	2
22	3	4	2	2	4	2	4	5	5	5
23	4	3	2	2	3	3	4	5	3	5
24	3	4	2	2	3	3	2	3	4	5
25	3	3	1	1	3	4	3	4	5	5
26	1	3	1	1	3	3	4	4	3	3
27	2	3	1	1	3	3	4	5	5	2
28	3	4	3	3	3	3	4	4	4	5
29	4	4	2	2	3	4	4	3	3	4
30	3	5	3	3	5	3	5	3	4	5
31	3	3	1	1	2	3	4	4	3	3
32	5	3	2	1	1	4	4	3	3	2
33	4	4	4	4	4	5	5	5	5	4
34	0	4	2	2	4	0	5	5	4	4
35	3	3	3	4	4	4	4	4	4	4
36	4	4	3	3	3	3	2	4	4	5
37	2	3	1	1	2	2	2	2	2	2
38	2	4	3	3	3	3	3	4	3	4
39	0	0	0	0	0	0	4	5	5	4
40	4	4	3	3	4	3	3	5	4	4
41	3	4	3	3	5	3	3	4	4	4
42	3	3	3	3	3	2	3	3	3	3
43	2	4	3	3	3	3	2	3	3	5
44	4	5	2	0	5	3	3	3	3	5
45	3	4	3	2	2	3	3	4	3	4
46	4	5	5	5	5	4	4	4	0	4
47	4	4	2	2	2	3	3	3	3	3
48	3	3	3	4	3	3	3	4	3	4
49	3	4	2	3	3	3	3	2	3	4
50	4	4	2	2	4	3	3	3	3	3
SUM	158	181	119	112	155	149	163	182	169	189
MEDIAN	3	4	2	2	3	3	3	4	3	4
AVERAGE	3,16	3,62	2,38	2,24	3,1	2,98	3,26	3,64	3,38	3,78
ST.DEVIATION	1,25	1,03	1,28	1,3	1,15	1,12	0,99	1,14	1,1	1,11
VARIANCE	1,57	1,06	1,63	1,7	1,32	1,24	0,97	1,3	1,22	1,24

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