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Integrating Building Planning and Design Process

Creating synergy between building's structure, materials and form

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Abstract— **This paper elaborates on the evolution of architectural form, building materials and structural solutions in the building planning and design process (BPDP), which is heavily conditioned by science and the level of technological advances, as well as by the roles of the key players (designers and engineers) in that process. The goal of conducted analysis is to, based on the values of traditional and conventional approach to building planning and design, come up with such system of designed/built environment, which will not jeopardize the complex system of a given/natural environment. By comparing the traditional (comprehensive, masterful work) and conventional (fragmented, specialized) approach to BPDP, it could be concluded that what is good in the old one is its holistic, integrated nature; while the new opportunities provided by a joined development of science and technology are benefits of the current moment, i.e. conventional BPDP.**

Keywords— architectural form, building materials, structural solutions, complexity, holistic approach, integration

I. Introduction

Humankind continuously strives for growth and progress, constantly increasing demands that can be met only at the expense of natural resources. Accordingly, as designers and builders, impressed by new technologies, ever more design and construct buildings that become technological systems, a shift away from the old, tried and tested models is clearly noticeable. Over the time, the key players in the building and design process become separated from the each other, form built environment they created; while buildings itself became distanced from the given (natural and designed) environment.

The past two centuries, the era from the beginning of the Industrial Revolution, were characterized by rapid industrial and population growth. This fast development was based on unlimited use of earth's resources. Parallel with depletion of natural resources, economic development, and population expansion brought increasing waste production, and pollution of water, soil, and air.

Population boom (a six-fold increase in two hundred years), along with industrialization forced building industry to answer to enormously increased needs for built structures. Thus, it was necessary to provide proper accommodation for numerous industrial workers, industry itself, as well as for other facilities that followed development. (Bijedić, 2012)

The architecture and related engineering disciplines responded to those demands by using new technological opportunities, which were offered by scientific and technology developments. Such approach created self-sufficient structures that were not any more respecting given, local opportunities and constrains, but were relying on highly sophisticated new materials and engineering supporting systems. Those newly invented materials and building systems, in most cases, use much more energy for their production and operations, than materials and systems known before the Industrial Revolution. All this led us to the stage where we have become more dependent on the earth that we were actively degrading. (Bijedić, 2012)

II. Synergy within Building and Given Environment

A. *Development of BPDP over the Time*

Throughout history, people have developed a variety of concepts in order to create comfortable and pleasant conditions within the building. Original concepts relied on climate, geographical location, availability of building materials, as well as the cultural and ritual aspects of certain societies. The main characteristic of such approaches was integrity, where on the one hand, the building was treated as one entity, and at the same times a unique composition of newly constructed and given environment was created on holistic manner.

Known or unknown builder was for a long historical period, all till the building was divided on several isolated systems, the one who was aware of the interdependence and interactions between all segments of the building. At the same time he fully respected given, natural and designed, environment whilst placing new built structures soundly incorporated in existing surrounding. Traditional builder, through his masterful work, treated building itself and building and environment as one, thus had a holistic approach to BPDP (Figure 1.).

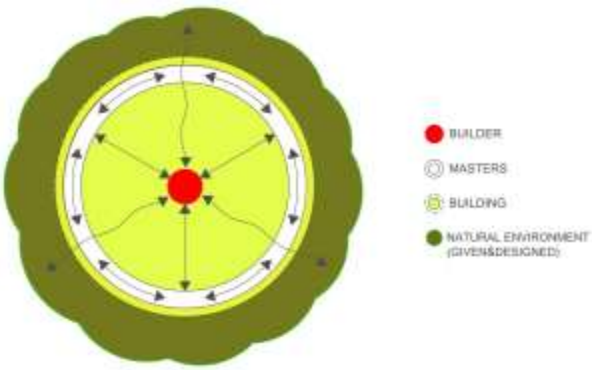

Figure 1. Masterful work – sound relation between new building and given environment

By changing relationship to nature, which means accepting the conviction that nature can completely be controlled by knowledge and achievements of science and technology, man, and builder as well, detach himself from the local physical, social or cultural environment and related opportunities and constrains. All this resulted by unsustainable, uncomfortable, impersonal, often unpleasant and energy demanding buildings. This, at the end, results in careless exploitation of resources (Roodman, 1996).

Contemporary, conventional approach in architectural and construction practice is strongly characterized by fragmentation. Fragmentation has evolved in parallel with the increase in the number of specializations in the disciplines related to building projects. Separation processes within the BPDP made very hard, for key players of BPDP, perceiving the building as a whole. Understanding a building as unique entity is of utmost importance for establishing the synergy between building elements and systems.

Steadman notes that the "subject matter of building science has until recently been made up from separate topics in the study of building materials, building elements, engineering structure, and the environmental behavior of enclosures in terms of heat, light and sound." (Steadman, 2008)

The role of chief architect or main designer in such projects is merely coordination of activities performed by a number of separate specialists among whom there were no direct essential connections (Figure 2).

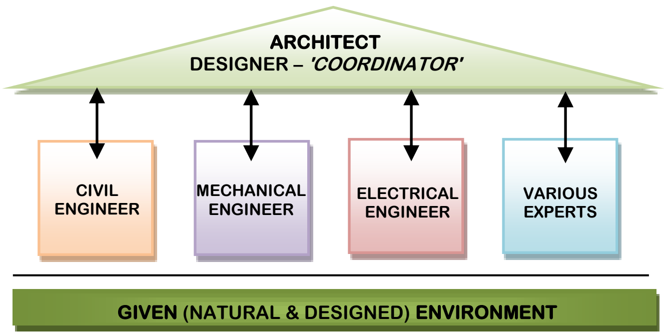

Figure 2. Separation and fragmentation - main characteristic of conventional BPDP

Today's builders (architects and engineers) have the ultimate goal of producing the building design integrated with the structural system. This includes achievement of efficiency, cost-effectiveness, aesthetics, durability, elegance, all while respecting environmental limits, as well as the overall impact that buildings will have on the local and global environment. These specifications urge them to rethink about what kinds of changes in BPDP are necessary in order to reduce the negative impact that buildings have on the environment.

B. *Complexity of Given – natural and designed Environment*

Approaching building and design process with aim to produce environmentally sound built environment, requires deep changes in philosophy and thorough knowledge system approach. Namely, in the system of the given (natural and designed) environment interaction, interdependence and consequences of the interrelationships of its sub-systems are so intertwined that abstraction, isolation and neglect of these complex conditions becomes impossible. The natural system, which we are deeply disturbing by interpolating built environment systems, requires architects and engineers to rethink on how they conduct their businesses. This new way of thinking should be guided by the principles of the relatively recent discoveries and theories in science that highlight the much greater complexity of the world, by far the greater complexity of the relationship, than what was thought for many years.

Elaborating on the complexity, Briggs questioned a practice of shaping the world by "lifeless mechanically interacting fragments driven by mechanical laws and awaiting our reassembly and control." (Briggs, 1992) He suggested another approach based on more complex models and geometries such as fractal geometry that could unify diversity of parts in nonlinear way, without predictability, allowing the life and creativity.

In that light Steadman sees opportunity in the integration of different areas of building science through properties such as geometric organization of parts and structure, topological relations of spatial segments and networks of circulation routes. (Steadman, 2008) Building form, as a material structure, determines the structural assembly by geometry of scale and sizes and functional connectivity of the components, with each other and with the whole. The geometry that determines these relationships is not classical geometry of linear composition, but the geometry of complex structures that reveal coordination with natural organic systems.

Answering the current problems, we must consider the theoretical basis for drawing specific variables from the domain of built environment, based on the on fundamental principles that are sustaining Earth system as a whole. In this sense, a general approaches proposed by Yeang's 'Law of ecological design', and Pearce-Vanegas's 'The operational framework for the sustainability of the system built environment', could be base for further elaboration.

Yeang claims that an open system may simply be conceptual or theoretical framework that should provide designer with a basis for making decisions about which environmental aspects to include in the synthesis of the project. At the same time, it should provide the basis for a comprehensive review of all other interdependent factors relating to the project. (Yeang, 1999)

Pearce and Vanegas, in their 'operational framework', also based on the principle of an open system, examine the parameters that can be used in defining sustainability. This is done by identification of critical thresholds that represent the boundary between sustainability and unsustainability of the system, and describe the area of decision-making. (Pearce, 2002)

These authors, although using different terminology, in their considerations include two basic systems: (1) a global system – i.e. – the system of the natural environment; and (2) technological system – i.e. – designed system.

As a starting point in determining the variables that affect the situation in interaction between each of these two main systems, it is necessary to define border areas, ie. the transfer point - or - thresholds of sustainability.

These border areas play a vital role in sustainable design, especially because bad project at transfer points often results in damage to the ecosystem.

Architectural built space, as a dynamic system, reveals multileveled functional and structural complexity. New spatial concepts in architecture should integrate multivariate shapes, sizes, and dimensions, in organic holistic way. Abstract geometric models of such concepts that could be applied on material structural level should be based on synthetic and complex approach, unifying built forms with complexity of the natural environment. Built forms could become integrated with higher levels of environmental complexity, maintaining diversity and continuous transformation in space and time, in organic, holistic approach. (Bijedić., 2013)

Buildings are ultimately the result of searching for the best solutions regarding function, technology, environment, comfort, security, stability, as well as the aesthetics. The designers have ultimate request to treat all those requirements simultaneously during all stages of building design and planning process, thus enabling other stages of building materialization to take the same path. Abstract and material dimensions of the design product and design processes must be mutually intertwined and conditioned, integrating building materials, structures and technological advances with utility and aesthetic.

Seeking order out of chaos we do not even have to worry about whether our prediction is completely objective, or subjective, because as Weizsäcker notes that: "The concept of probability is one of the most striking examples for the 'epistemological paradox' that we can apply our basic concepts successfully without really understanding them." (Weizsacker, 1985)

C. *Various Answers to Building's Requirements*

The end of the twentieth and beginning of the twenty-first century are characterized by a further understanding of the essence of architecture. Understanding the relationship between the structure and architectural form, enables authors to simultaneously examine the importance of form, function, structure, as well as materials related to the final product - the building. Those issues are now, in addition, being analyzed and assessed in terms of energy efficiency, cost, location and the building's overall environmental impact, certainly not neglecting other requirements exposed by the architectural rule of thumb.

Making right decisions is the key to success, in all our activities, as well as in a given context. Accordingly, decisions regarding the selection of the structural system will directly influence the decision on materialization, and vice versa. This will, in turn, significantly affect the service installation systems; the very disposition of interior partitions, functionality and aesthetics, all of which will directly predetermine the entire form of the building.

To establish integration within the components of the building requires, primarily, establishment of synergies between structures and materials. Knowledge of geometry of form, new technologies and the ability to interact one system with another, is a prerequisite for finding good solutions.

Therefore, the area that integrates previous discipline is geometry. The importance of geometry has come into focus by invention of pre-stressed concrete and its standardization. The close connection of geometry and structural solutions has evolved to the invention of new materials, used for new structural types, like membrane and pneumatic structures. An example is the use of new materials in constructive solutions for strained 3D surfaces, which led to the re-integration of design and engineering skills. Since the last decade of the 20th century architects and engineers increasingly rely on the usage of computer aided design tools. With the support of computer programs, as well as familiarity with the performance of building materials, different approaches in the search for form, allow calculation of the optimal solution for a given geometrical parameters.

Solutions can be obtained by applying the finite element analysis (FEA - Finite Elements Analysis). The process of searching the optimal structural form is carried out by means of CAD and FEA programs, such as 2D or 3D CAD models introduced into the FEA environment. The confrontation of the two applications is defined and reveals the geometric model structured of small elements and nodes in a structural assembly. Knowing the performance of the used materials, computer software procedures determine the strain, tension and pressures that will result after the expected structural loads. The results are discussed with the help of tools to visualize FEA environment, where it is possible to identify stress and variations in surface analysis results.

The adoption of these new technologies has led to significant advances in the understanding of built space. As an example, membrane structures redefined the concept of internal and external space, shifted the dimension limits, and produced the aesthetic of form soundly corresponding to the given environment. (Bijedić, 2012)

Geometric model is based on abstraction that enables focused attention on the essences of spatial forms, their orientation, dimensions and overall patterns of connections, through different parameters and structural interpretations. Classic geometric spatial representations are based mainly on two perpendicular levels, horizontal and vertical. It must be emphasized that every specific level must be considered in integrated multidimensional space that envelops different scales and projections. Different sub levels must be integrated and comprehended in complex open-loop structure of development and transformations, on multi-scaled levels, from general whole to particular details. Geometric model in complex approach is multidimensional and multileveled. (Bijedić, 2013)

Only a whole system integrated approach, which simultaneously treats the individual elements and connections, i.e. the details which correspond to the forces they are exposed to, selection of materials that provide the best resistance to these forces, and removing materials that are not essential for the structural integrity, undoubtedly, leads to optimal, aesthetically unique, environmentally sound solutions.

The wealth of possibilities obliges designers and the engineers to integrate the achievements of science and technology to the practice, seeking interactions among all elements, phases, participants, as well as all other components of the BPDP.

III. New Paradigm

Contemporary science, as well as today's scientists and practitioners, accept paradigm shift from mechanistic to organic. In the sense of a dramatic change of the worldview, the architectural and engineering theories and methodologies are no exception. It is evident that throughout the history of architecture, many methodologies mirrored certain aspects of ecological considerations, and thus shaped the vision of a new paradigm.

Not going back to the old, which after all is not feasible, respecting the new, the following emerges: (1) the process must be reintegrated through a new organizational structure based on a new paradigm; (2) participants in the process must constantly be in interactive communication, creating multidisciplinary partnerships; and (3) a new philosophy more oriented towards the respect of nature, instead dominating over it, must be adopted.

If these guidelines are accepted, the workflow can be illustrated by a model that vividly recalls the flower. This should introduce, instead of an old paradigm: 'house is a machine for living', the new one: 'house is a flower'. This suggests that buildings should be designed similarly like nature designs flowers, which even belonging to the same species, growing in different forms, and sizes depending on climate, terrain composition, insulation, and geography location. (Figure 4.)

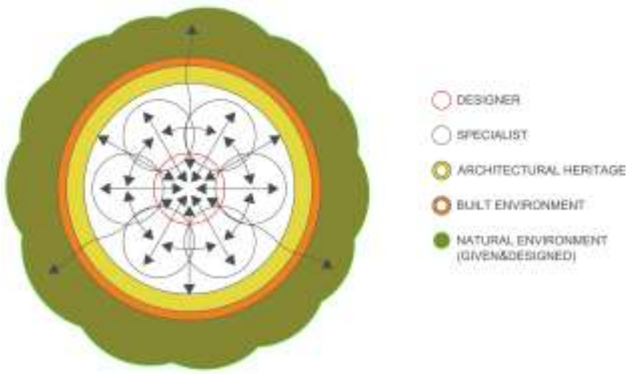

Figure 3. Multydisciplinary partnershp - key characteristic of integrated BPDP

Thus, it is clear that the links and 'interweaving' partners in designing a multidisciplinary team; and interactive relationships of the new-designed environment, relying on architectural heritage, the built and natural environment, must be established, and this will be possible only after the change of philosophy that today runs a BPDB.

Considering the problems arising from the current approach BPDP, holistic and anticipatory approach proves imminent. Holism is, in itself, the all-inclusive and all-encompassing, and according to the complexity theory, can not be determinative, but only forecasting and predicting.

Thus, in order to achieve the minimum negative, while the maximum positive impact of inclusion designed to give the (natural and designed) environment imposes the necessity of defining the overall characteristics of a responsible approach to be able to predict the effects of built structure on the environment. This applies to both, the immediate, local, and to a wider, global environment.

From the material plane, properties of physical space-structures are transposed to abstract plane that provides simplified control and prediction of the complex spatial problems. Simplification on the abstract levels demands integrated approach on different levels of abstraction, enveloping all subsystems in holistic unity.

After comparing common, conventional, fragmented and separated practice to the old, integrated, holistic approach to creation of built space, it could be concludes that BPDP can synthesize individual elements in one whole. This should be done with the aim: not to offer a final solution that could prevent and heal all the causes and consequences of the current way of planning and design of buildings, but above all, provide insight into various aspects of the damage that the resulting building may cause. As a consequence of the identification of potential damage sources, it will be much easier to provide solutions that will change over time and evolve depending on the technical possibilities of the moment.

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