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Editorial

Architecture and Engineering: The Challenges—Trends—Achievements

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Abstract: The current Special Issue is addressed to architects and engineers. Design and research are areas connecting their activities. A review of 17 published articles confirms the fact that the interface between architecture and engineering is multidimensional. The ways of finding points of contact between the two industries are highlighted. This is favoured by the dynamically changing reality, supported by new design paradigms and new research techniques. The multi-threaded subject matter of the articles is reduced to six blocks: research scopes, methods, design aspects, context, nature of research, and economy and cost calculation. Each of the articles in these six blocks has its weight, and so, in the "Nature of research" block, the following areas have been underscored: laboratory tests, in situ research, field investigations, and street perception experiments. The "Design aspects" block includes design-oriented thinking, geometrical forms, location of buildings, cost prediction, attractor and distractor elements, and shaping spatial structures. The new design and research tools are an inspiration and a keystone bonding architects and engineers.

Keywords: architecture; engineering; design paradigms; research methods; circular building; sustainability; spatial structures; design-oriented thinking; BIM; MCDM; SVM

1. Introduction

The keystone binding the articles in the presented Special Issue is design understood as the activity that the architects and engineers engage in. Part of the dynamically changing reality is the emergence of new design paradigms. New architectural, functional, and technological solutions as well as research methods are constantly researched in order to (inter alia) ensure a good indoor climate while achieving energy and economic efficiency. This search coincides with the paradigms of sustainable development which, as the submitted articles show, have become a permanent fixture in our collective awareness.

We can see that the importance of knowledge, knowledge-based design, building physics, technical building equipment, and circular economy is constantly increasing. Modelling and digitization in architecture and civil engineering have become commonplace in research and design.

New, broadly understood technologies also involve changes in the forms of organizing a designer's work, organizational changes in all entities of the investment process, manifested in the Integrated Project Delivery (IPD), and integrated management. Concepts such as architect—engineer—contractor—user are becoming inseparable.

Individual industries participate in the advanced design process but they should not work in isolation, because it only favours linear design.

The intention of the current Special Issue is to indicate the possibilities of finding points of contact between these industries, especially between architects and engineers. The selected, constantly evolving design techniques and research methods presented in this issue are intended to foster this integration.

2. Contributions

The current Special Issue includes 17 articles. They are all original research papers; no review articles or technical reports have been published in this issue.

A total of 34 authors or co-authors from three countries, Belgium, Israel, and Poland, took part. Of this number, as many as 47% are architects or people associated with architectural institutions (universities, administration). In total, 10 of the 17 articles are those with the participation of architects. The fact that architects are actively involved in academic research, especially on the borderline with engineering, is encouraging. The reader is offered a decent dose of selected references. The total number is 827 quoted publications.

Despite the profiling of the subject matter of the articles, the interface between architecture and engineering is multi-threaded.

The scope of these articles, relations between the indicated threads, various aspects, and applications of research results can be grouped into several blocks. Their outline is presented in Figure 1. Six blocks have been distinguished: research scopes, methods, design aspects, context, nature of research, and economy and cost calculation. Each of the articles in these six blocks has its weight.

One can express satisfaction that almost all authors make a direct or indirect reference to sustainability. Of the few important articles (listed in the "Context" block), two are truly spectacular.

Majerska-Pałubicka and Latusek [1] have focused on the issue of development of a degraded riverside quay in an inner-city environment. The proposed research method includes in situ research, with consideration of legal and historical aspects, as well as the condition of the built-up and natural environment. The result of this inquisitive research is a multifunctional complex meeting the paradigm of sustainable development, while the historic city of Cracow (Podolski Boulevard) is the beneficiary of this research.

The field research presented in [2] answers the questions of how urban planning and architecture, i.e., how spatial and geophysical conditions specific to a given place, may affect the quality of the living environment. The presented in-depth research in an industrial piedmont village relates to the morphological structure of buildings, the degree of their modernization, and types of heating systems. The concept of urban ventilation, which is well explained here, is worth a closer look.

All the examples which show that the dilemmas (faced by architects in the area of sustainability) are still valid, as identified in [3]. However, they also clearly show that these dilemmas can be solved.

The block entitled "Methods" (Figure 1) contains many attractive methods and approaches, ranging from BIM (with aspects) to parametric design. The design thinking method is also presented. Let us discuss five of them here.

Tymkiewicz introduces us to the world of the image of sustainable smart cities. The author demands that the image be created primarily by architects. He claims that the roles and tasks faced by architects change, which he highlighted in his article [4]. He refers to the so-called six building blocks of a smart city. The author also recommends a kind of creative approach to design, i.e., the design thinking method. Pilot studies confirm this approach.

The issues of dynamically developing BIM appear in as many as three articles. Finally, we are dealing not with theory but with the implementation of BIM technology in the architectural and construction industry. In [5], Zima at al. perform a SWOT analysis (Strengths–Weaknesses–Opportunities–Threats) to assess how BIM application is used. The implementation of BIM (e.g., in Poland) currently has a favourable position on the market, resulting from the existence of its strengths. The authors indicate that the best strategic solution for the implementation of BIM technology is an aggressive development strategy, recommended in "maxi-maxi" situations. Today, such a topic does not need promotion because it promotes itself.

The leitmotif of the article (by Maskil-Leitan et al. [6]) is BIM and green buildings, but what is essential is BIM management benchmarking. The Green BIM Index has been introduced to assess the level of BIM and green building integration. The conclusions are drawn from the assessment of nine cases. The article bridges the gap between information modelling and the social system.

The issue of parametric design, so attractive in recent years, is the centrepiece of the next article [7]. Rhinoceros, Grasshopper, and Karamba 3D software is commented and the calculations are supported by the finite element method (FEM). However, genetic algorithms are the primary research instrument. These tools were used in shaping curvilinear steel bar structures that are hyperbolic paraboloid canopy roofs. The methods presented here are attractive to both designers and architects.

Evaluation of design solutions is the core of the design. Methods from the group multi-criteria decision-making (MCDM), among others, are used to this end. Ogrodnik [8] uses the application potential of these methods to locate single-family residential buildings with solar installations. The author points out that analytic hierarchy process (AHP) and its modification, i.e., the AHP fuzzy method, are the most suitable methods for these considerations. It is a significant example of the potential of MCDM methods in evaluating architectural designs. The author's approach is in line with the achievements of Professor E. K. Zavadskas [9]. The group of MCDA methods is indicated as particularly useful in solving problems at the interface of architecture and engineering (c.f. Zavadskas et al. [10], Saaty and De Paola [11]).

The group of papers identified in the "Economy and cost calculation" block looks interesting.

Construction costs are of interest to both engineers and architects, especially early estimates of the costs. Juszczyk [12] presents the results of his research on the development of a cost forecasting model, and the subject of his analysis design is bridge construction. The original cost forecasting model is based on machine learning, i.e., support vector machines (SVMs). Several SVM-based regression models were tested, and the proposed model was tested for the required accuracy.

However, Cambier et al. [13] clearly emphasise the design for circularity. Circulation and the function of the building are concepts from the realm of the circular economy. BIM is treated as a process here, with an indication for the integration of BIM with LCA. The required design aid tools, as well as three urgent research paths, have been identified. The article is addressed to architects, developers, and researchers. Circulation becomes a symbol of combining architecture and engineering, i.e., architectural design and engineering solutions.

Nowogońska and Korentz [14] present issues at the interface between technical solutions and costs. Buildings' age, or rather their technical condition, changes, measured by the degree of wear. Thus, we have two basic issues: costs of renovation and repair works of a building and methods of calculating the degree of technical wear. The article uses the prediction of reliability according to Rayleigh distribution (PRRD) model. Of course, the analysis of the technical condition and the application of this method was carried out in the area of housing construction. The method can be generalized and used in other types of construction.

From the collection of submitted articles, it is possible to sublimate a group in terms of the way the research was carried out, namely the "Nature of research" block. Here are the distinctive items (from perception experiments to laboratory research).

The first article in this group [15] focuses on perception—more precisely, on the visual perception of selected buildings. The research was based on the "eye-tracking research" method. These methods, known in psychology, have been successfully transferred to the area of architecture and urban planning. In this case, eye-tracking measurement is based on recording two types of information: fixations and saccades. The research was conducted on the perception of works of architects in Cologne and the following was established: (a) attractors (elements that attract one's attention) and (b) distractors (elements that distract one's attention). The so-called Generation Z participated in the research.

This group of articles also includes article [2], discussed earlier, on field research. Classic laboratory test results are included in [16,17].

Article [16] is a structural analysis of a brick building. New building materials and new technologies require specific solutions to work out the way to join walls. Jasiński and Galman discuss ways to join walls using autoclaved aerated concrete (AAC) masonry elements. The discussion was supported by laboratory tests and numerical analysis using FEM (finite element method). The analyses focus on the morphology and the mechanism of joint damage.

The next article (Kubissa et al. [17]) combines laboratory testing with ecological issues. Concrete with waste copper slag was tested, taking into account its natural radioactivity and types of cement. Concrete was assessed using the Ecological Index and Performance Index (EIPI) method, which takes into account the Ecological Index (EI) and Performance Index (PI). The Gross Ecological and Performance Indicator (GEPI) was used as a support indicator.

The Research scope block gathers all of the articles, some of which are covered under different, distinctive blocks. This block shows a variety of topics (c.f. Figure 1).

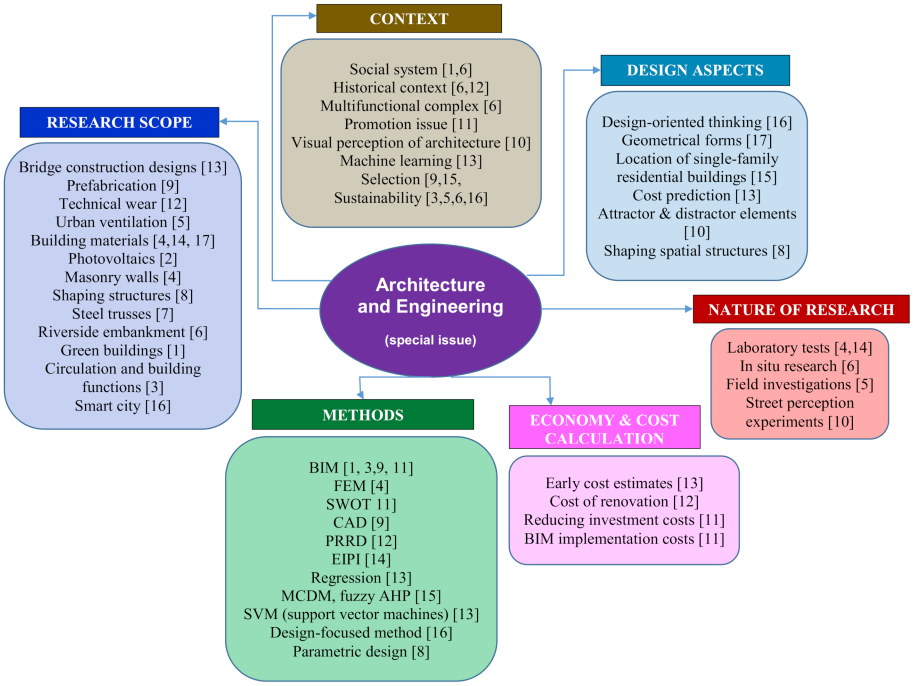

Figure 1. Research areas of case studies and their dominants.

The search for a symbiosis of balanced development and digitization is extremely valuable, and it is popular because it allows the use of intelligent systems—in this case, control at the stage of highly specialized assembly and maintenance of the structure [18]. The use of logical algorithms, Monte Carlo simulations, and CAD elements made it possible to develop an interactive method of computer-aided assembly planning. Moreover, the presented research is part of the trend of the increasing use of prefabrication in construction.

Architects and investors' distrust of photovoltaic solutions in construction is dispelled by Celadyn and Filipek [19]. The systematization of knowledge in the area of photovoltaic systems (modules) is addressed mainly to architects. The architect's attitude, the design process, savings, and the desired energy efficiency are underscored. The outlined vision is promising. Ultimately, this will allow designing structures with zero energy consumption.

In engineering and architecture, new technological developments which affect the design and implementation of high-rise buildings are commonplace. The architects Szołomicki and Golasz-Szolomicka [20] call attention not only to the geometric form but also to development trends; they bring up the issue of the growing importance of composite materials.

This block ends with article [21]. It is easy to notice that the hollow section structures embellish architecture. The article by Broniewicz and Broniewicz [21] is devoted to this issue, offering designers the most up-to-date information on welds for so-called lap joints. The article is addressed to designers of steel structures and is directly applicable in determining the quality of joints between bars of truss connections.

3. Discussion and Comments

Each of the published articles can be classified into the "Research scope" block—see Figure 1—and each of them includes at least several threads that could be included in several of the following five blocks, or even in additional blocks. All this proves that the presented issues are multi-threaded and multi-layered.

In this Special Issue, the design paradigms are less emphasized; research has clearly dominated this issue. There is a green light for digitization and applications such as IoT (Internet of Things), VR (Virtual Reality), AR (Augmented Reality), and the transition from 3D to 7D modelling. At the interface between architecture and engineering, we would be pleased to see solutions such as those originating from bionic engineering or kinetic architecture. The concept of architectural IQ should not be considered in terms of the future but in terms of the present.

The issues at this interface are broad and open. Requirements engineering, both in terms of product engineering and process engineering, might offer assistance here. The possibilities of using requirements engineering specifically in architectural design and its importance in introducing the principles of sustainable development into architectural practice are explained in [22].

Technical progress on this matter alone will not solve these problems. There are many contributing factors, even legal ones. For example, European Union directives bring an important dimension, including the directive on the energy performance of buildings (i.e., Directive 2010/31/EC), which introduced the concept and obligation to design and implement nearly zero energy buildings (nZEB).

An open society pays close attention to operating costs in building life cycle analysis. All of this creates new challenges for architects and engineers.

4. Conclusions

A review of the 17 published articles shows that the interface between architecture and engineering is multidimensional.

There are many paths at the interface between architecture and engineering and not all have been identified on this issue. There are many common and complementary problems. This is an area and an incentive for further research.

The implementation of Integrated Project Delivery (IPD) and BIM (especially BIM as a process) turned out to be an important element, conducive to the integration of architectural and engineering activities. This is why designing has evidently become a team game.

What the analysis of the research presented in this Special Issue has revealed is that apart from the sustainability paradigm, there are other elements which intensely affect the interface between architecture and engineering, namely (a) Circular Building (according to the Circular Economy principles), (b) multi-criteria decision support, e.g., MCDM (as a tool for evaluation, comparison, selection, and optimization), and (c) parametric design.

The presented research emphasizes the fact that new design tools do not divide but connect subjective industries. They constitute a strong current inspiring them and binding them together.

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References

1. Majerska-Pałubicka, B.; Latusek, E. A Concept of the Development of Riverside Embankment in the Context of Cracow (A Local Centre). *Buildings* **2020**, *10*, 56. [CrossRef]
2. Blazy, R. Living Environment Quality Determinants, Including $PM_{2.5}$ and PM_{10} Dust Pollution in the Context of Spatial Issues—The Case of Radzionków. *Buildings* **2020**, *10*, 58. [CrossRef]
3. Bonenberg, W.; Kapliński, O. The Architect and the Paradigms of Sustainable Development: A Review of Dilemmas. *Sustainability* **2018**, *10*, 100. [CrossRef]
4. Tymkiewicz, J. The Role of an Architect in Creating the Image of an Elderly-Friendly Sustainable Smart City. *Buildings* **2019**, *9*, 223. [CrossRef]
5. Zima, K.; Plebankiewicz, E.; Wieczorek, D. A SWOT Analysis of the Use of BIM Technology in the Polish Construction Industry. *Buildings* **2020**, *10*, 16. [CrossRef]
6. Maskil-Leitan, R.; Gurevich, U.; Reychav, I. BIM Management Measure for an Effective Green Building Project. *Buildings* **2020**, *10*, 147. [CrossRef]
7. Dzwierzynska, J. Multi-Objective Optimizing Curvilinear Steel Bar Structures of Hyperbolic Paraboloid Canopy Roofs. *Buildings* **2020**, *10*, 39. [CrossRef]
8. Ogrodnik, K. Multi-Criteria Analysis of Design Solutions in Architecture and Engineering: Review of Applications and a Case Study. *Buildings* **2019**, *9*, 244. [CrossRef]
9. Kaplinski, O.; Peldschus, F.; Nazarko, J.; Kaklauskas, A.; Baušys, R. MCDM, operational research and sustainable development in the trans-border Lithuanian-German-Polish co-operation. *Eng. Manag. Prod. Serv.* **2019**, *11*, 7–18. [CrossRef]
10. Zavadskas, E.K.; Antucheviciene, J.; Kaplinski, O. Multi-criteria decision making in civil engineering: Part I—A state-of-the-art survey. *Eng. Struct. Technol.* **2015**, *7*, 103–113. [CrossRef]
11. Saaty, T.L.; De Paola, P. Rethinking Design and Urban Planning for the Cities of the Future. *Buildings* **2017**, *7*, 76. [CrossRef]
12. Juszczyk, M. On the Search of Models for Early Cost Estimates of Bridges: An SVM-Based Approach. *Buildings* **2020**, *10*, 2. [CrossRef]
13. Cambier, C.; Galle, W.; De Temmerman, N. Research and Development Directions for Design Support Tools for Circular Building. *Buildings* **2020**, *10*, 142. [CrossRef]
14. Nowogońska, B.; Korentz, J. Value of Technical Wear and Costs of Restoring Performance Characteristics to Residential Buildings. *Buildings* **2020**, *10*, 9. [CrossRef]
15. Lisińska-Kuśnierz, M.; Krupa, M. Suitability of Eye Tracking in Assessing the Visual Perception of Architecture—A Case Study Concerning Selected Projects Located in Cologne. *Buildings* **2020**, *10*, 20. [CrossRef]
16. Jasiński, R.; Galman, I. Testing Joints between Walls Made of AAC Masonry Units. *Buildings* **2020**, *10*, 69. [CrossRef]
17. Kubissa, W.; Jaskulski, R.; Gil, D.; Wilińska, I. Holistic Analysis of Waste Copper Slag Based Concrete by Means of EIPI Method. *Buildings* **2020**, *10*, 1. [CrossRef]
18. Marcinkowski, R.; Banach, M. Computer Aided Assembly of Buildings. *Buildings* **2020**, *10*, 28. [CrossRef]
19. Celadyn, W.; Filipek, P. Investigation of the Effective Use of Photovoltaic Modules in Architecture. *Buildings* **2020**, *10*, 145. [CrossRef]
20. Szolomicki, J.; Golasz-Szolomicka, H. Technological Advances and Trends in Modern High-Rise Buildings. *Buildings* **2019**, *9*, 193. [CrossRef]
21. Broniewicz, M.; Broniewicz, F. Welds Assessment in K-Type Joints of Hollow Section Trusses with I or H Section Chords. *Buildings* **2020**, *10*, 43. [CrossRef]
22. Bonenberg, W. Requirements Engineering as a Tool for Sustainable Architectural Design. In *Advances in Human Factors, Sustainable Urban Planning and Infrastructure*; Charytonowicz, J., Ed.; Springer: Cham, Switzerland, 2018; Volume 600, pp. 218–227. ISBN 978-3-319-60449-7.