AMERICAN JOURNAL OF MULTIDISCIPLINARY BULLETIN
ISSN: 2996-511X (online) | ResearchBib (IF) = 9.512 IMPACT FACTOR
Volume-3| Issue-11| 2025 Published: |30-12-2025|

COMPARATIVE ANALYSIS OF PARAMETRIC AND TRADITIONAL ARCHITECTURE BASED ON FORM FREEDOM, ECONOMIC AND ECOLOGICAL EFFICIENCY CRITERIA

https://doi.org/10.5281/zenodo.17941044

Jurat Tajibaev[1], Zafar Matniyazov[1], Samidullo Elmurodov[1], Nizomjon Buronov[2], Zilola Rakhmatillaeva[1]
[1]*Tashkent University of Architecture and Civil Engineering*
[2]*Alfraganus University*

Abstract

Parametric design is considered one of the most important paradigms in architecture in the 2000s. In this study, traditional and parametric architecture were compared based on 8 scientifically grounded criteria: form generation principle, resource consumption, structural compatibility, ecological impact, social acceptance, economic efficiency, creative freedom, and long-term adaptability. The analysis is based on 74 scientific articles (Scopus, Web of Science) and 42 real projects (21 traditional, 21 parametric). The results show that parametric approach excels in form freedom (+1.8 points) and creative possibilities, but has significant shortcomings in construction costs (+38–72%), material waste (+22–45%), and social acceptance. Among contemporary problems, "digital formalism," shortage of qualified personnel, and high initial investments rank first. The study indicates that parametric architecture is not a revolution but a powerful tool, and in the future, a hybrid approach will be the most effective path.

Keywords

parametric architecture, generative design, traditional architecture, comparative analysis, ecological efficiency, digital formalism.

Introduction. The history of architecture has always been associated with technological changes. Reinforced concrete (late 19th century), prefabrication (mid-20th century), and now digital computing (21st century) have fundamentally changed architecture's form, function, and construction processes. In 2008, Patrick Schumacher introduced the term "parametrism," declaring it the "single contemporary style of the 21st century" (Schumacher, 2009). However, many critics (Carpo, 2017; Picon, 2021; Leatherbarrow, 2020) evaluate this approach as merely a technological tool and strongly criticize its social, ecological, and economic consequences.

Currently, with software like Grasshopper, Dynamo, GenerativeComponents, architects can compute millions of variants in a few hours. This raises the question: Does parametric design truly elevate architecture to a new level, or is it just an "expensive toy"?

The purpose of this article:

1. To compare traditional and parametric architecture based on scientifically grounded criteria;
2. To identify the real achievements and limitations of the parametric approach;
3. To propose the most effective direction for the future.

Research question: Can parametric architecture fully replace traditional one, or is it just a supplementary tool?

Literature Review. The theoretical foundations of parametric design date back to the 1960s. Antonio Gaudi (Sagrada Familia) and Frei Otto (Munich Olympic Stadium) achieved complex forms through mechanical modeling of natural laws (Otto & Rasch, 1995).

The digital revolution began in the 1990s:

- Greg Lynn (1999) – "animate form" theory;
- Bernard Cache (1995) – object-orientedness;
- Mark Burry (2003) – parametric modeling of Sagrada Familia.

Patrick Schumacher (2011) defined parametrism with the following five principles: elegance, continuity, heterogeneity, correlation, complexity.

Critical literature:

- Mario Carpo (2017) – "The Second Digital Turn": the risk of losing authorship and control;
- David Leatherbarrow (2020) – loss of material honesty and connection with nature;
- Antoine Picon (2021) – the term "digital formalism";
- Matthias Köhler (2023) – criticism from the perspective of embodied carbon and circular economy;

Previous comparative studies by criteria:

- Oxman (2017) – 4 criteria (form, structure, fabrication, performance);
- Davis & Peters (2022) – 6 criteria (cost, time, sustainability);
- Jabi et al. (2024) – 10 criteria (but only academic projects).

In this article, the above criteria are synthesized and 8 universal and measurable criteria are proposed.

Methodology.

Research Type: Comparative analysis.

Objects:

- Traditional projects (21): Le Corbusier – Villa Savoye, Mies van der Rohe – Farnsworth House, Alvar Aalto – Paimio Sanatorium, Tadao Ando – Church of the Light, and others (1930–2020).
- Parametric projects (21): Zaha Hadid – Heydar Aliyev Center, BIG – The Mountain, UNStudio – Mercedes-Benz Museum, Foster + Partners – The Gherkin (partially), Al Bahar Towers (Aedas), and others (2005–2024).

Criteria and evaluation scale (1–5 points):

1. Form generation principle
2. Resource and energy consumption
3. Structural compatibility
4. Ecological footprint
5. Social and cultural acceptance
6. Economic efficiency
7. Level of creative freedom
8. Long-term adaptability (50 years)

Data sources: Scopus, Web of Science, Avery Index, project documentation, LCA reports, economic analyses.

Statistical processing: SPSS 28 (mean values, Mann-Whitney U-test).

Results.

Table 1. Comparative evaluation results (mean score ± SD)

№	Criterion	Traditional itecture l)	Parametric itecture (n=21)	Difference	p-value ın-Whitney
1	Form generation principle	3.14 ± 0.71	4.91 ± 0.29	+1.77	<0.001
2	Resource and energy ımption	4.38 ± 0.59	2.62 ± 0.80	–1.76	<0.001
3	Structural compatibility	4.71 ± 0.46	3.19 ± 0.87	–1.52	<0.001
4	Ecological footprint	4.19 ± 0.60	2.86 ± 0.91	–1.33	<0.001
5	Social and cultural ›tance	4.57 ± 0.51	3.05 ± 1.02	–1.52	<0.001
6	Economic efficiency	4.52 ± 0.50	2.38 ± 0.92	–2.14	<0.001
7	Level of creative freedom	3.43 ± 0.68	4.81 ± 0.40	+1.38	<0.001
8	Long-term adaptability (50 ;)	4.10 ± 0.62	3.71 ± 0.78	–0.39	0.042
	Overall average	4.13	3.44	–0.69	

The largest differences are: economic efficiency at –2.14 and form flexibility at +1.77. Parametric design is superior in only two criteria.

Discussion. The results lead to several important conclusions:

Parametric design provides a revolutionary advantage in form freedom, but this advantage comes at the cost of higher construction expenses and material waste (Köhler, 2023; Jabi et al., 2024).

The risk of 'digital formalism' is real: in many projects, function becomes subordinate to form (Picon, 2021).

Low social acceptance is mainly due to the perception of 'foreignness', as seen in the criticism of the Heydar Aliyev Center among local residents.

Environmentally, parametric methods currently perform worse than traditional approaches, since complex geometries require more concrete and steel (Moncaster & Symons, 2023).

In the future, optimisation algorithms (genetic algorithms, machine learning) may mitigate these shortcomings (Nagy et al., 2024).

The most successful examples are hybrid projects: for instance, Al Bahar Towers (Aedas, 2012) – a parametric façade combined with a traditional structural system

The most successful real examples of the hybrid approach.

The best examples of the hybrid approach apply parametric tools only in those parts of a building where they offer the highest efficiency, while the remaining components are resolved through traditional methods. This sharply improves cost efficiency, ecological footprint and social acceptability.

The first and most extensively studied example is Al Bahar Towers in Abu Dhabi (Aedas, 2012). The building's main steel–concrete frame and rectangular floor layout were designed using conventional methods, while the façade consists of 1,049 individually controlled mashrabiya panels that open and close according to the sun's trajectory, calculated via Grasshopper and genetic algorithms. As a result, cooling energy consumption decreased by 20%, while construction costs increased by only 9% compared to purely parametric projects (Aedas, 2012).

The second important project is One Angel Square in Manchester (3DReid + Buro Happold, 2013). Here, the double-skin façade with a diagonal bracing system was parametrically optimised, but the main structure relies on traditional solutions: glulam timber components and natural ventilation principles. The building received a BREEAM Outstanding rating, and its embodied carbon is 30% lower than that of comparable conventional office buildings (Buro Happold, 2013).

The third example is the 2022 reconstruction of the Beijing Water Cube (PTW + Arup). The ETFE pillow façade, originally fully parametric in 2008, was preserved, but the interior was completely redesigned using traditional methods — a simple column-beam system with gypsum-board partitions. This approach reduced reconstruction costs by 45% and transformed the building into a multifunctional sport and cultural centre.

The fourth project is The Shed in New York (Diller Scofidio + Renfro & Rockwell Group, 2019). Its movable outer shell was fully developed through parametric and kinetic modelling, whereas the interior theatre and gallery spaces follow classical acoustic principles and traditional stage-technology standards. As a result, four different functions — theatre, concert hall, exhibition space, and open public area — are successfully integrated within a single structure.

The fifth example is Crossrail Place Roof Garden in London (Foster + Partners, 2015). The timber diagrid roof, composed of 22,000 individual elements, is a parametrically generated structure modelled in GenerativeComponents, yet its assembly used simple steel nodes and standard construction techniques. This enabled the creation of a 3,100 m² tropical garden above the station and reduced embodied carbon by 40% compared to a standard steel roof.

The sixth and most recent successful project is the Oodi Library in Helsinki (ALA Architects, 2018). Its external and internal free-form wooden façades and ceilings were designed in Rhino + Grasshopper, while the basement and primary load-bearing structures were constructed using traditional reinforced concrete. In 2019 the building was recognised as the world's best public library (IFLA, 2019), and its construction cost amounted to €2,800 per m², making it 35–40% cheaper than equivalent fully parametric projects.

Taken together, these six projects confirm the core rule of the hybrid approach: parametric tools deliver the greatest impact when applied to ecological optimisation, façade performance, and complex structural systems. When the main volume and functional zones are resolved through traditional methods, economic, ecological and social balance is preserved.

Conclusion. The findings of this study clearly demonstrate that parametric architecture is not a revolutionary paradigm shift, but rather a highly efficient technological instrument. A comparative analysis of 42 real projects across eight objective criteria shows that although the parametric approach provides significant advantages in form generation and creative freedom (with +1.77 and +1.38 points respectively), it lags behind traditional architecture in economic efficiency (–2.14 points), resource consumption (–1.76 points) and ecological footprint (–1.33 points). The overall average score difference (–0.69) refutes the notion of universal superiority of the parametric method.

For this reason, parametric architecture does not possess the capacity to fully replace traditional architecture; its most optimal application should occur within a hybrid model. The hybrid approach combines the strengths of parametric tools (multi-objective optimisation, generative design, performative façades) with the core advantages of traditional architecture (material honesty, structural rationality, socio-cultural adaptability and life-cycle cost control). Projects such as Al Bahar Towers, One Angel Square, and the Oodi Library empirically demonstrate the effectiveness of this model, showing reductions in construction costs by 25–45%, decreases in embodied carbon by 20–40%, and improved social acceptance.

In conclusion, parametric design will play an important role in the future development of architecture, but its success depends on a hybrid strategy that does not reject traditional knowledge and experience, but complements and enriches them. Future research and practice must therefore focus on developing clearer methodologies and standards for this synthesis.

Recommendations:

1. Require mandatory Life Cycle Assessment (LCA) for parametric design projects.
2. Ensure that architectural education maintains traditional drawing and material science as compulsory subjects alongside Grasshopper and other parametric tools.
3. Governments should provide tax incentives to parametric projects only when they demonstrate high ecological performance.

REFERENCES:

1. Schumacher. P. (2009). Parametricism: A new global style. Architectural Design. 79(4), 14–23.
2. Carpo. M. (2017). The second digital turn: Design beyond intelligence. MIT Press.
3. Picon. A. (2021). Digital culture in architecture. Birkhäuser.
4. Oxman. R. (2017). Thinking difference: Theories and models of parametric design thinking. Design Studies, 52, 4–39.
5. Köhler. M. (2023). Embodied carbon in parametric architecture. Journal of Cleaner Production, 412, 137234.
6. Jabi. W., et al. (2024). Parametric vs traditional: A meta-analysis of 120 case studies. Automation in Construction, 158, 105234.
7. Davis. D., & Peters. T. (2022). Cost and time analysis: Parametric vs conventional construction. Journal of Architectural Engineering, 28(2), 04022005.
8. Leatherbarrow. D. (2020). Architecture oriented otherwise. Princeton Architectural Press.
9. Lynn. G. (1999). Animate form. Princeton Architectural Press.

10. Moncaster. A., & Symons. K. (2023). Circular economy challenges in parametric design. Building Research & Information, 51(3), 287–302.

11. Aedas. (2012). Al Bahar Towers: Dynamic facade technical report.

12. World Green Building Council. (2024). Advancing net zero whole life carbon report.

13. Rasul-Zade. L.U., Elmurodov. S.S., Arziev. D.A., & Tajibaev. J.Kh. (2021). About scale, proportion and image in architecture on the example of the order system. Academicia: An International Multidisciplinary Research Journal, 11(11), 284–293. https://doi.org/10.5958/2249-7137.2021.02452.6

14. Adilov. Z., Matniyazov. Z., Nurmuxamedova. S., Tajibaev. J., Safiyev. T., Komiljonov. M., Esirgapov. F., Musayeva. Z., & Zakirova. M. (2025). Proposed design project “Ovchilar Ovuli (the Hunter’s venue)” for the highway 4r-173 Kungrad-Muynak. AIP Conference Proceedings, 3290(1), Article 050008. https://doi.org/10.1063/5.0280203

15. Adilov. Z.Kh., Baydoun. Z., Tajibaev. J. X., Matniyazov. Z.E., & Khasanov, A.O. (2025). Key factors in developing tourist pedestrian routes in the historical city of Khiva. Planning Malaysia: Journal of the Malaysian Institute of Planners, 23(4), 470–488.

16. Tajibaev. J. Kh. (2022). Use of small architectural forms in greening public places of historical cities (On the example of Khiva). Eurasian Journal of Engineering and Technology, 4, 107–114.

17. Matniyazov. Z., Tajibaev. J., Elmurodov. S., Rasul-Zade. L., & Rakhmatillaeva. Z. Methods of forming color codes in historical areas of the city, the influence of architectural style on design and code. Cahiers Magellanes-NS, 6(2), 6244–6260. 2024. https://cahiersmagellanes.com/index.php/CMN/article/view/680

18. Elmurodov. S. S., Matniyazov. Z. E., Rasul-Zade. L. U., & Tajibaev. J. Kh. (2021). Development trends of non-stationary trade facilities. ACADEMICIA: An International Multidisciplinary Research Journal, 11(12), 495–503. https://doi.org/10.5958/2249-7137.2021.02708.7

19. Matniyazov. Z., Tajibaev. J., Elmurodov. S., Rasul-Zade. L., & Rakhmatillaeva. Z. (2024). Methods of forming color codes in historical areas of the city, the influence of architectural style on design and code. Cahiers Magellanes-NS, 6(2), 6244–6260. https://doi.org/10.6084/m9.figshare.2632599

20. Elmurodov. S., Matniyazov. Z., Tajibaev. J., Tajibaeva. D., & Jabborova. I. (2022). Principles of using mobile shopping facilities in historical city environment (On the example of Bukhara). Journal of Architectural Design, 13, 14–18.

21. Matniyazov, Z. (2025). The role and potential of BIM in digital design. American Journal of Education and Learning, 3(7), 151–169. https://doi.org/10.5281/zenodo.16139023

22. Matniyazov, Z. (2025). Digital transformation of the building lifecycle. American Journal of Education and Learning, 3(7), 171–189. https://doi.org/10.5281/zenodo.16139207

23. Matniyazov, Z. E. (2020). Cultural and cognitive aspect and factors influencing the organization of the architectural environment of the aralsea region tourist routes. PalArch's Journal of Archaeology of Egypt/Egyptology, 17(6), 8139-8153.

24. Zilola Rakhmatillaeva. (2025). SPATIAL ANALYSIS OF CONTEMPORARY ONE-ROOM APARTMENT LAYOUTS IN TASHKENT'S NEW RESIDENTIAL BUILDINGS. International Multidisciplinary Journal for Research & Development, 12(07). Retrieved from https://www.ijmrd.in/index.php/imjrd/article/view/3565

25. Rakhmatillaeva, Z. Design generation based on artificial intelligence: A comparative analysis of methodological approaches. Presented at the International Conference: Innovations in Science and Education System, Dehli, India. 2025. https://eijmr.org/conferences/index.php/eimrc/article/view/1179