Exploring the Synergy and Conflict Between Architectural Aesthetics and Actual Construction

Zhengwu Jia

MArch Architecture Design+Build, The University of Nottingham, Nottingham, NG7 2RD, United Kingdom

alyzj18@nottingham.ac.uk

Abstract. With the wide application of parametric modeling, virtual reality (VR) technology and new building materials, architectural design has presented unprecedented technological vitality and formal creativity. However, innovative design faces a series of severe challenges in the actual construction process, including unstable costs, limited construction feasibility, and the disconnection between existing industry norms and emerging technologies. These problems have gradually marginalized architectural aesthetics in the dominant logic of technical implementation and construction management, making it difficult to be fully reflected in the finished products. This study focuses on "the synergy and conflict between architectural aesthetics and actual construction", systematically exploring the practical predicaments in architectural innovative design practices from three levels: technical means, professional collaboration, and institutional mechanisms. The research adopts the literature analysis method and combines typical cases such as the Nanjing Youth Olympic Conference Center to analyze the compression and compromise mechanisms of aesthetic expression in the processes of parametric design, application of new materials and multi-disciplinary collaboration. The research results show that architectural aesthetics is gradually losing its decision-making power and realization path in the current design and construction system oriented by efficiency, cost, and standardization. The technical process that prioritizes efficiency, the risk-avoidance strategies under marketization pressure, as well as the language barriers and imbalance of discourse power in professional collaboration, all lead to the systematic weakening of aesthetic value in construction practice.

Keywords: Construction Feasibility, Multi-Disciplinary Collaboration, Technological Innovation, Standardization Pressure.

1. Introduction

In the field of contemporary architectural design, the rapid development of innovative technologies is profoundly changing design thinking and construction logic. Pan introduces that the wide application of means such as parametric modeling, digital simulation, virtual reality (VR), and new building materials has brought architects greater formal freedom and design efficiency, and has also promoted the continuous optimization of architectural space in terms of structural performance and sustainability [1]. However, with the in-depth practice of these technical means, their application effects also face certain practical challenges. For instance, Charles thinks that the accuracy deviation between the design model and the actual construction, the increased difficulty in cost control during the construction process, and the uneven technical maturity often make it difficult for construction projects to realize the original concept at the implementation stage [2]. Furthermore, the current regulatory system and technical standards in the construction industry show obvious lag when confronted with the rapidly developing innovative means, creating a "time dislocation" between them and the cutting-edge design practices. Designers are often forced to make compromises between creative expression and compliance constraints, thereby affecting the integrity of the design and the realization of architectural aesthetics.

Based on the above problems, this study focuses on the core topic of "the synergy and conflict between architectural aesthetics and actual construction", attempting to explore the operational bottlenecks and potential optimization paths of the multi-disciplinary collaboration mechanism on the basis of systematically sorting out the current status of technological development. On the one hand, this research is conducive to an in-depth understanding of the role and limitations of technological innovation in promoting architectural creative expression. On the other hand, it also provides theoretical support and institutional suggestions for resolving the tension between "design ideals" and "construction realities".

2. Background

In recent years, the architectural industry has shown increasing attention to the "contradictory relationship between technological innovation and aesthetic realization". This study mainly conducts an analysis from three dimensions: Firstly, it explores the application predicaments and feasibility challenges of the current mainstream innovative design methods in practical engineering; Secondly, analyze the efficiency advantages and communication

barriers of the multi-disciplinary collaboration mechanism in the implementation of architectural design; Thirdly, reflect on the institutional deficiencies and improvement space in the collaborative mechanism of the construction industry by combining typical cases. The research adopts the literature analysis method to systematically sort out the existing academic research, policy standards and practical cases. This method can comprehensively grasp the application situation of current technical means and collaborative practices, and is conducive to revealing the deep-seated reasons for the collaborative imbalance between architectural aesthetics and actual construction.

The goal of this study is to clarify the main conflicts between innovative design and industry norms, identify the communication bottlenecks in multi-disciplinary collaboration, and on this basis, propose specific optimization strategies. To achieve this goal, this paper will take representative architectural projects as the case basis, analyze the key nodes and collaborative mechanisms in their design and construction processes, and then propose the path conception of achieving the "minimum compromise" between architectural aesthetics and the implementation of technology.

3. Illustrate the Cost Issues and Feasibility Risks of Using Innovative Means in the Design

Brozovsky pointes out that with the development of architectural design technology, parametric design, virtual reality (VR) technology, and innovative building materials have been widely applied by designers in the practice of the construction industry, greatly expanding the possibilities of architectural form expression [3]. However, at the same time, Brozovsky (2024) also emphasizes that these innovative measures are often accompanied by high uncertainties, especially in terms of economic costs, construction accuracy, and maintenance stability, where there are many practical problems. This section will combine specific design cases to explore the actual costs and feasibility risks that designers face when applying innovative means.

3.1. Unstable Costs and Design Risks

Parametric modeling and VR technology have become important tools for designers to break through the limitations of traditional design and achieve complex architectural spatial forms in recent years. These tools, through special algorithms and model visualization simulations, can quickly generate expressive architectural forms. For instance, landmark projects such as the renowned Guangzhou Opera House and Beijing Daxing Airport have all demonstrated the strong visual effects and spatial experiences brought by parametric design. However, in specific project practices, parametric design also shows certain cost instability and construction risks.

Take the Nanjing Youth Olympic Conference Center (designed by Zaha Hadid Architects) as an example. According to the case study of GRCA, its unique streamlined building facade was generated through parametric design tools, presenting a highly attractive visual effect [4]. However, during the construction process, due to the overly complex curved surface of its shape, the precise processing of the steel structure is difficult, resulting in a large number of errors during the installation of the curtain wall. As a result, multiple reworks have to be carried out to meet the design requirements of the plan. Such repeated corrections and adjustments have significantly increased the construction cost and also prolonged the overall construction period.

On the other hand, Wu indicates that although VR technology can help designers and clients understand the space more intuitively, experience the design effect in advance and communicate effectively [5]. However, the virtual effects it presents often fail to fully reflect the complexity and uncontrollable factors existing in the real construction site. For example, the lighting simulation in the virtual environment may ignore the changes in light under actual climatic conditions, and the color and texture of the materials are different from those in the real scene in the model. In addition, during the on-site construction process, there may also be situations where the quality does not meet the standards due to operational errors of the construction personnel or fluctuations in material supply. Xie believes that all these factors will increase the construction risks to a certain extent, forcing the project to constantly make adjustments and rework on site, thereby raising the subsequent construction costs [6]. Although parametric design and VR technology have effectively expanded the expressiveness and possibilities of architectural design, in specific practice, the construction industry finds it difficult to precisely control various details during the construction process, thereby significantly increasing the risks and uncertainties of the project in the implementation stage.

3.2. The Conflict Between the Ecological Benefits of New Materials and the Feasibility of Large-Scale Application

Firoozi points out that emerging building materials, such as ecological materials, structural materials, and building materials oriented towards sustainable development, have been widely used in the construction industry in recent years, aiming to promote the realization of green, energy-saving, and sustainable design goals [7]. Chen finds that these materials usually demonstrated good performance in experimental studies and small-scale pilot projects [8]. However, when emerging buildings are introduced into large-scale design, the contradiction between the ecological value of materials and the feasibility of construction gradually emerges, becoming an important limiting factor affecting their promotion and application.

First of all, according to Ayarkwa, the relatively high initial investment cost is one of the main problems in the promotion process of new materials [9]. Take photovoltaic glass curtain walls as an example. This material theoretically has a good energy recovery capacity and can reduce energy consumption in building operations by converting solar energy. However, compared with traditional glass curtain walls, the procurement, installation and later maintenance costs of photovoltaic glass are relatively high. This high initial cost ultimately limits the possibility of its wide application.

Secondly, the lack of technology and construction experience during the construction process also leads to a gap between the actual effect of the application of new materials and the expected results. For instance, in the micro-renovation project of Lingyun Community in Shanghai, the design team adopted a new type of permeable concrete material, aiming to enhance the rainwater infiltration capacity of the site. However, due to lax control over the base layer laying and unskilled construction techniques, the materials have encountered problems such as substandard strength and frequent cracking. These quality risks not only weaken the ecological benefits of the materials themselves, but also increase the economic burden of later maintenance and repair.

In addition, the lack of long-term performance monitoring of materials and unified implementation standards has become a key factor restricting the promotion and application of emerging materials. Pan explains that at present, many emerging materials have not yet been incorporated into the technical specification system of the construction industry, and there is a lack of systematic and long-term assessment of their safety, durability and environmental adaptability. Construction units lack reliable basis in material selection and practical application, while developers face more uncertain risks and responsibilities, leading them to choose materials more conservatively. This lag in regulation and data support has also, to a certain extent, weakened the confidence and acceptance of new materials in the construction industry.

4. The Efficiency Advantages and Communication Challenges of Multi-Disciplinary Collaboration

Nahyan states that with the increase in the scale and complexity of construction projects, multi-disciplinary collaboration has become an important means to promote the efficient operation of the construction process [10]. The simultaneous intervention of specialties such as architecture, structure, and mechanical and electrical engineering is conducive to improving design efficiency and shortening the construction period. However, Nahyan also points out at the same time that in actual operation, due to the lack of unified design standards and standardized communication mechanisms, there are still errors in information transmission among different specialties, which may lead to design conflicts and decision-making delays.

4.1. Work Efficiency

In contemporary construction projects, the complexity and diversity of the projects require collaborative work among various specialties to meet the requirements of multiple aspects such as spatial layout, structural force, and energy consumption control. Ren introduced that multi-disciplinary collaboration, by integrating specialties such as architecture, structure, mechanical and electrical, and landscape to intervene simultaneously, turns the workflow among various specialties into a more compact parallel mode [11]. This approach significantly enhances the response speed of the early-stage plan and helps to identify and resolve potential conflicts as early as possible, thereby reducing the frequency of modifications and cost waste in the later construction stage.

Furthermore, the introduction of digital collaboration tools has further enhanced the interaction efficiency among specialties. Means such as BIM, collaborative cloud platforms, and real-time model synchronization tools not only enhance the immediality of design scheme transmission but also promote information visualization, making it easier for various specialties to understand the overall design goals. This approach can effectively reduce the design cycle of large and complex projects and lower the cost and time loss caused by the modification rate.

4.2. The Lack of Unified Design Standards Leads to Information Deviations in Communication

Awomolo emphasized that although the multi-disciplinary collaborative working mode has achieved remarkable results in improving efficiency, in the actual construction process, due to the differences in the design ideas, language expression methods and design specifications adopted by each discipline [12]. During the design process, different specialties usually carry out their work based on the standard systems within their respective industries. For example: Architects often focus on the aesthetic integrity and usage logic of the design; Structural engineers, on the other hand, focus on construction safety, while mechanical and electrical designers center on the efficiency of building system layout and the convenience of maintenance. This kind of collaboration disparity caused by different and industry standards not only affects communication efficiency, but also may lead to rework and resource waste during the construction stage, thereby weakening the efficiency advantage that collaboration should possess.

Therefore, to truly leverage the effectiveness of multi-disciplinary collaboration, it is not only necessary to rely on the introduction of technical tools, but also to establish unified design standards and information expression methods to ensure the accurate transmission and timely response of information among multiple disciplines.

5. The Phenomenon that Architectural Aesthetics is Gradually being Marginalized

In the current design process dominated by efficiency, constructability and visual logic, architectural aesthetics is often simplified as an "unnecessary" secondary goal. Design decisions tend to comply with parameter logic, material standards and cost constraints, and the space for formal exploration is significantly compressed, resulting in the continuous weakening of aesthetic intentions in technical implementation.

5.1. Aesthetic Expression is Suppressed by the Priority of Technical Efficiency

In the current architectural design process oriented towards efficiency and constructability, aesthetic expression is gradually being marginalized and has become a non-core goal that is easily sacrificed. Brozovsky considers that Design practice is increasingly dominated by modeling parameters, construction logic and construction constraints, and form generation increasingly takes "visual efficiency" rather than "cultural expression" as the primary judgment criterion [13]. Especially with the wide use of digital platforms such as BIM, architectural design has been restructured into a high-density information organization and collaborative operation activity, and aesthetic judgment has been forced to give way to the priority consideration of accuracy, structural rationality and system integration. Matthews finds that during multiple rounds of consultations with structural consultants, mechanical and electrical engineers, and cost estimators, architects often need to make continuous technical "fine-tuning" to the original design scheme to adapt to the standard component system or reduce the construction complexity, thus causing the initial formal concept to be constantly compressed and compromised [14].

This trend was particularly typical in the Nanjing Youth Olympic Conference Center project. This project was designed by Zaha Hadid Architects. Its streamlined facade was generated through parametric modeling, presenting a strong visual tension and sculptural effect. However, according to the report of GRCA during the actual construction stage, due to the high complexity of the curved surface structure, the precision of the steel structure is difficult to meet the installation requirements, resulting in a large number of errors in the curtain wall system during construction. As a result, multiple reworks have to be carried out to meet the construction standards, ultimately leading to cost overruns and project delays. During this process, some of the original designs were simplified or weakened to adapt to the pressure of construction efficiency and cost control, resulting in a significant gap between the actual expression of architectural aesthetics and the initial conception.

More broadly speaking, this phenomenon of "technology suppressing aesthetics" is somewhat common in the construction industry. Charles indicates that during the process from the winning bid proposal to the implementation stage of many public building projects, due to factors such as the replacement of standardized modules, the adjustment of material performance and the review of specifications, the aesthetic intention is often gradually diluted layer by layer [15]. The spatial rhythm, light and shadow penetration, and material texture envisioned by architects often fail to be fully presented in the completed works in the end. It can be said that in the current technology-driven design and production system, architectural aesthetics has regressed from the core of decision-making to an accessory result of visual packaging. This trend not only weakens the cultural expression and form experimentation capabilities of architecture, but also exposes the structural problem that the current design process lacks institutional maintenance of aesthetic value.

5.2. Marketization Pressure Prompts Design to Tend towards Safety and Replicability

In a market environment dominated by speed delivery and cost control, architectural design is facing an increasingly obvious tendency towards homogenization and conservatism. Awomolo proposes that in order to increase the probability of winning bids in the highly competitive bidding and development process, many design institutions tend to adopt a "low-risk" expression strategy, that is, relying on mature forms and modular composition systems that have been verified by the market [16]. This strategy ensures the controllability and approval efficiency of the design scheme to a certain extent, but it also invisibly restrains the space for formal innovation and aesthetic challenges, resulting in architectural aesthetics being gradually marginalized as a secondary goal that can be compromised in the design process.

Firoozi support that this trend is particularly evident in the development of large public buildings and commercial residential properties. Under the dual pressure of rapid delivery nodes and cost early warning mechanisms, the design team often proactively reduces the use of complex facades, unique structures or non-standard materials to lower the construction difficulty and cost fluctuation risks [17]. The shift of design from innovative spatial exploration to the replication and application of "template architectural language" constitutes a "low-risk strategy" in aesthetic expression. For instance, in multiple commercial complexes and residential communities in cities, the facade design tends to adopt a uniform window-to-wall ratio, color matching and modeling vocabulary of modules, resulting in a large number of projects being homogenized in form, lacking individual expression and cultural tension.

Furthermore, the bid evaluation mechanism and the market-oriented preferences of the client have further exacerbated this phenomenon. In the bidding and tendering system, "feasibility", "cost control" and "construction experience" are often set as priority evaluation indicators, while the assessment of architectural form, spatial aesthetics and place spirit is relatively absent. This orientation enables design institutions to prioritize meeting the technical review needs of construction teams and cost consultants in resource allocation, rather than preserving the integrity of artistic expression. Ultimately, architectural aesthetics has become an expression that "exists in renderings but is difficult to reach construction drawings", and has been included in the "deletable" sequence since the early design stage.

6. Conclusion

The research results of this study show that although innovative design techniques such as parametric modeling, VR applications and the use of new materials have greatly expanded the expression possibilities of architectural forms, they often face multiple practical challenges such as high costs, implementation risks and regulatory obstacles in the actual construction process, thus resulting in the systematic compression of the expression of architectural aesthetics at the practical level. The research further concluded that the current design-construction logic oriented towards efficiency and cost has invisibly weakened the core position of aesthetics, and the multi-disciplinary collaborative mechanism lacking unified standards and institutional support has also exacerbated the compromise and deviation of design intentions in the implementation stage.

This research has important reference value for future architectural practice and theoretical research. On the one hand, it reveals the structural contradiction between the promotion of innovative design and the realization of aesthetics in the current construction industry, prompting architects, engineers and institutional makers to reflect on the existing collaboration and management processes. On the other hand, it provides the industry with strategic suggestions on how to maintain aesthetic integrity while ensuring technical feasibility, which is highly practical and inspiring.

Future research should focus more on the optimization of cross-professional collaboration mechanisms, the institutional embedding of architectural aesthetic value, and the continuous expression of aesthetic achievements throughout the design process. In particular, it is necessary to explore through empirical research, policy analysis and case tracking, etc., how to construct a more integrated and culturally sensitive architectural design management system under the trend of rapid construction and technical standardization, so as to achieve true synergy between innovative design and actual construction.

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