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# THE STRUCTURAL AND THERMOELECTRIC PROPERTIES OF MAGNESIUM SULPHIDE ($MGS_2$) CHALCOGENIDE

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**Abstract:** The pursuit of efficient and sustainable energy conversion technologies has led to a growing interest in the exploration of novel materials with enhanced thermoelectric properties. In this study, we employ first-principles calculations to investigate the structural and thermoelectric characteristics of Magnesium Sulfide (MgS2) Perovskites Chalcogenide, a promising candidate for thermoelectric applications. Our investigation begins with a comprehensive examination of the structural properties of MgS2, delving into the crystal structure, lattice parameters, and bond lengths. Utilizing density functional theory (DFT) and ab initio simulations, we elucidate the electronic structure of MgS2, uncovering crucial insights into its band structure, density of states, and band gap. The electronic properties are explored to understand the nature of charge carriers and their mobility within the material. Furthermore, the thermoelectric properties of MgS2 are thoroughly analyzed, including the Seebeck coefficient, electrical conductivity, and thermal conductivity. Through the calculation of the figure of merit (ZT), we assess the thermoelectric efficiency of MgS2 under varying conditions, such as temperature and doping levels. Our study aims to identify optimal parameters for enhancing the thermoelectric performance of MgS2, which is crucial for applications in waste heat recovery and power generation. The investigation extends to the impact of different crystal structures, chemical compositions, and external factors on the thermoelectric behavior of MgS2, providing a comprehensive understanding of its potential in diverse thermoelectric applications. Insights gained from this study contribute to the ongoing effort to develop efficient and sustainable materials for thermoelectric devices, thereby facilitating advancements in energy harvesting and utilization. In conclusion, our first-principles study of MgS2 Perovskites Chalcogenide sheds light on its structural and thermoelectric properties, offering valuable guidance for the design and optimization of materials in the quest for improved thermoelectric performance.
**Keywords**: Thermoelectric properties; Chalcogenide; DFT calculations; BoltzTrap

## 1 INTRODUCTION

Thermoelectric materials have gained considerable attention in recent years for their potential applications in converting waste heat into electricity and solid-state cooling devices. -based materials are particularly promising due to their tunable properties. In this study, we focus on the Magnesium sulfide [MgS2] as a candidate for thermoelectric applications. Using a first principles approach based on density functional theory (DFT), we investigate its structural stability, electronic band structure, and thermoelectric transport properties. Thermoelectric materials are crucial for converting waste heat into usable electrical energy and for solid-state cooling applications. -based compounds have garnered interest due to their tunable electronic and thermal properties. In this study, we focus on the Magnesium Sulfide chalcogenide [MgS2] as a potential thermoelectric material. The first principles approach using density functional theory (DFT) is employed to explore its structural stability, electronic band structure, and thermoelectric transport properties. The pursuit of efficient thermoelectric materials has been fueled by the growing need for sustainable energy solutions. Thermoelectric materials can directly convert heat into electricity, making them vital for waste heat recovery and solid-state cooling applications. -based materials have gained considerable attention due to their tunable properties, offering a promising avenue for enhancing thermoelectric performance. In this project, we delve into the exploration of the Magnesium Sulfide [MgS2] as a potential candidate for thermoelectric applications.
The importance of thermoelectric materials lies in their ability to address critical energy challenges, such as waste heat recovery from industrial processes and vehicle exhausts. These materials can also be used in compact solid-state cooling devices, reducing the reliance on energy-intensive and environmentally harmful refrigeration technologies. Thus, there is a pressing need to identify novel thermoelectric materials with enhanced performance and stability [1] . compare interhemispheric exchange periods with sulfur hexafluoride ($SF_6$) age to assess interhemispheric transport simulations. The researchers examine how well the dynamics of air exchange between the Northern and Southern Hemispheres are captured by the models that are currently in use. Their results point to differences between simulation projections, indicating that greater modeling is required to comprehend atmospheric transport processes. The bandgap, an essential parameter for thermoelectric materials, was found to be within the desirable range for efficient energy conversion, as reported by[2]. Several studies have investigated the thermoelectric transport properties of [MgS2][3]. reported a

significant positive Seebeck coefficient, suggesting the material can convert temperature gradients into electrical voltage efficiently.

Additionally, they highlighted the inherently low thermal conductivity of [MgS2], a crucial factor for thermoelectric materials, which further enhances its thermoelectric performance. On the other hand [4], explored the electrical conductivity and carrier mobility of [MgS2], providing insights into its charge transport capabilities. Efforts to enhance the thermoelectric performance of [MgS2] have been explored by several researchers. [5] investigated the potential benefits of alloying and doping in [MgS2], demonstrating improved thermoelectric properties through suitable chemical modifications. This suggests that optimization strategies could further elevate the material's performance. As the push for sustainable energy technologies grows, evaluating the environmental impact of materials like [MgS2] becomes essential. [6] conducted a life cycle assessment (LCA) to analyze the environmental sustainability of [MgS2]-based thermoelectric devices. Their study emphasized the need to consider not only the material's thermoelectric properties but also its ecological implications in the context of green energy technologies. First-principles techniques and the Boltzmann transport equation are used by [6] to determine the thermoelectric coefficients of n-doped silicon. A thorough grasp of the electrical characteristics influencing thermoelectric performance is provided by their research, which also offers suggestions for improving silicon-based thermoelectric materials. Recent developments in thermoelectric materials that improve waste heat recovery and renewable energy generating efficiency are reviewed by [7] , which Their results demonstrate how these materials have a great deal of promise to support environmental preservation and energy sustainability. An alternative green solution for turning waste thermal energy into electrical power is thermoelectric power generation, as discussed by [8] . Reviewing current patents and the fundamentals of thermoelectric production, their research emphasizes the benefits of increasing energy conversion efficiency without taking into account the cost of thermal energy intake. The ability of thermoelectric generators to transform waste heat into useful electricity is highlighted in [9] investigation of their potential as renewable energy sources. The study emphasizes how thermoelectric technology is effective in promoting sustainable energy solutions and how it improves the environment. The potential of thermoelectric materials to improve energy sustainability through waste heat recovery systems is covered by [10]. While conventional energy conversion techniques frequently result in substantial heat waste, the chapter emphasizes that thermoelectric generators (TEGs) can effectively capture this lost energy in a variety of applications, such as residential buildings and industrial processes. The goal of continuous research and development in thermoelectric materials is to enhance their performance and scalability for broad applications, notwithstanding obstacles such as high costs and low efficiency. [11] gives a summary of solar energy as a vital renewable resource, outlining its uses, methods, and possibilities in relation to the world's energy requirements. In addition to highlighting continuous developments in solar technology to improve efficiency and accessibility, the chapter emphasizes the significance of solar energy in lowering reliance on fossil fuels. The characteristics and uses of thermoelectric materials, which make it easier to convert heat into electricity and vice versa, are examined by [12]. The basic ideas underlying thermoelectric performance are covered in the article, along with developments in material design that attempt to increase efficiency for energy harvesting and cooling applications. The ecological and socioeconomic effects of oil spills are reviewed by [13], who highlight the long-term effects on ecosystems and communities. The authors offer a framework to direct preparation and response activities with the goal of improving readiness and lessening the negative social and environmental impacts of future spills. According to [14] , solar thermal energy has a lot of promise for effective energy production and heating applications but is sometimes disregarded in talks of renewable energy. In comparison to photovoltaic technology, solar thermal systems are more cost-effective and efficient. The study emphasizes these benefits and urges greater investment in this often-overlooked energy source. When [15] examine the electrical characteristics and stability of octagon-nitrogen (ON), a novel two-dimensional material, they discover that it is a dynamically stable semiconductor with an indirect band gap of 4.7 eV. The work shows that methods including stacking, biaxial tensile strain, and applying an external electric field can be used to efficiently design the band gap, indicating possible uses in electronics and optoelectronics. The structural, electrical, and thermodynamic characteristics of magnesium chalcogenide ternary alloys are examined by [16] . Their findings show that the composition of these materials significantly affects their band gaps and thermal stability. Since these alloys' characteristics may be adjusted, the work sheds light on their possible uses in optoelectronic devices. Using density functional theory, [17]calculate the electronic structures of the magnesium chalcogenides MgS and MgSe in order to examine their band structures and electronic characteristics. Regarding their applicability in semiconductor applications, the study concludes that both materials display unique electronic properties. The structural, magnetic, optical, electronic, and thermoelectric characteristics of $Gd_2MgS_4$ and $Tm_2MgS_4$ spinel sulfides are investigated by [18] using first-principles calculations. The study highlights the tunable capabilities of these materials based on compositional alterations, revealing interesting traits for possible use in thermoelectric devices. Using density functional theory, [19] do a first-principles investigation of the structural, electrical, elastic, and optical characteristics of the magnesium chalcogenides MgS, MgSe, and MgTe. The results reveal unique optical properties and electrical structures for every material, indicating their possible use in a range of fields, such as optoelectronics and catalysis.

The primary goal of this work was to examine the thermoelectric and structural characteristics of magnesium sulfide (MgS2) chalcogenide. In order to evaluate whether MgS2 chalcogenide is a good thermoelectric material appropriate for use in high-voltage or low-voltage devices, the study attempts to identify other aspects that may affect or influence its structural and thermoelectric capabilities. Whether magnesium sulfide (MgS2) has sufficient structural and thermoelectric qualities to be appropriate for electrical applications is the main research question. The central research

question is whether magnesium sulphide (MgS2) possesses adequate structural and thermoelectric properties to be suitable for electrical applications.

## 2 METHOD

This investigation thoroughly analyzed the Magnesium Sulphide (MgS2) compound, concentrating on its structural characteristics through Quantum Espresso in Density Functional Theory (DFT) simulations utilizing the PBE pseudopotential. The electronic structures underwent optimization to determine the ground state properties, with a cut-off energy of 80 Ry and a K-mesh order of 4x4x4 for optimal convergence. Following this, an examination of thermoelectric properties was carried out using the Boltzmann conductivity equation. All thermoelectric properties presented in this study were computed using the BoltzTraP code, covering transport properties such as the Seebeck coefficient, electrical conductivity, Power Factor, and thermal conductivity, as outlined in the work by [20].

### 2.1 Structural Properties

The below figure 1 depicts the crystallographic structure of Magnesium Sulphide in an orthorhombic form.

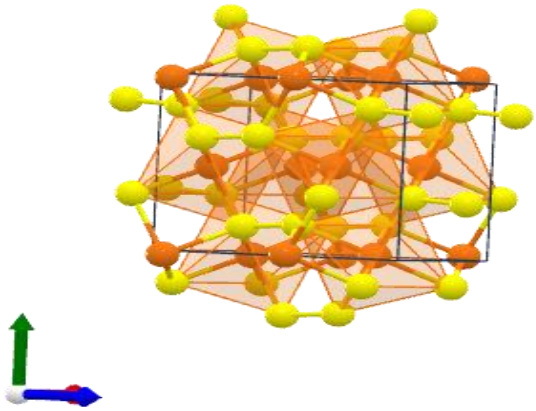

**Figure 1** The Crystallographic Structure of MgS2

The crystal structure of MgS2, adopting the orthorhombic Pnma space group, is illustrated below. All essential attributes of chalcogenides are presented. The visualization of the three-dimensional structure is utilized [21] . recommended software, X-Window Crystalline Structure and Densities (XcrySDen). Specifically, the program XcrySDEN, designed for displaying crystalline and molecular structures, was employed to represent iso-surfaces and outlines of the molecules, as depicted in Fig. 1. Graphs were generated using the XMGRACE plotting program. The obtained results closely align with the theoretical and experimental values of lattice parameters observed in related chalcogenides.The stability of the compounds was assessed using the Goldschmidt tolerance factor, calculated as

$$T = \frac{(r_A + r_B)}{\sqrt{2}(r_B + r_X),} \quad (1)$$

where rA, rB, and rX represent the ionic radii of the elements A, B, and X in the structure, respectively. The values are crucial for assessing the stability and distortion of crystal structures. The obtained results affirm the stability of the material, confirming its stable orthorhombic crystal structure.

### 2.2 Thermoelectric Properties

Boltzmann's transport theory offers a method for estimating thermoelectric transport coefficients with minimal computational efforts. This theory is particularly useful when studying the thermoelectric voltage generated by a temperature difference between two distinct materials. The phenomenon resulting from this temperature gradient, known as the Seebeck effect, gives rise to a voltage of several microvolts per Kelvin [9]. In the case of the MgS2 compound, both charge and thermal transport properties were analyzed using the generalized BoltzTraP program. This program relies on the electronic band structure to derive various transport coefficients, including the Seebeck coefficient denoted as S (measured in V $K^{-1}$). The Seebeck coefficient represents the ratio of the induced voltage to the temperature gradient and plays a crucial role in understanding a material's thermoelectric properties. The generalized BoltzTraP program facilitates the estimation of the Seebeck coefficient as a function of temperature (T). By examining the Seebeck coefficient's variation with absolute temperature and chemical potential (μ), the program provides valuable insights into the material's thermoelectric behavior. The integration of the transport equation is a key step in these calculations, enabling a comprehensive understanding of how the Seebeck coefficient evolves under different temperature and chemical potential conditions.

This approach allows researchers to explore and characterize the thermoelectric performance of MgS2 efficiently, shedding light on its suitability for applications involving thermoelectric energy conversion. The Seebeck coefficient, as

determined through Boltzmann transport theory, serves as a fundamental metric for evaluating the thermoelectric efficiency and potential applications of materials in the realm of energy harvesting and conversion. The integration of the transport equation enables the calculation of the Seebeck coefficient as a function of both absolute temperature (T) and chemical potential (μ). This process provides a comprehensive understanding of how the Seebeck coefficient varies under different temperature and chemical potential conditions, offering valuable insights into the material's thermoelectric behavior[6]. The Seebeck coefficient as functions of absolute temperature T and chemical potential μ can be calculated by integrating the transport equation.

$$\boldsymbol{S_{\alpha\beta}(\mathrm{T},\mu)} = \frac{1}{eT\,\Omega\sigma_{\alpha\beta}\,(\mathrm{T},\mu)} \int \boldsymbol{\sigma_{\alpha\beta}(\mathcal{E})(\mathcal{E}-\mu)}[\frac{\delta f_{\mu}(T,\mathcal{E})}{\delta\mathcal{E}}]\boldsymbol{d\mathcal{E}} \quad (2)$$

Where the energy projected conductivity tensor, denoted as $\sigma_{\alpha\beta}(\mathcal{E})$, encapsulates system-specific information and is expressed in terms of various parameters. Here, Ω represents the volume of the unit cell, *f* is the Fermi–Dirac distribution function, and *e* denotes the elementary charge. This tensor provides insights into the electrical conductivity of the system as a function of energy $(\mathcal{E})$, offering a means to characterize the material's electronic transport properties. The energy projected conductivity tensor, $\sigma_{\alpha\beta}$ (ε), which contains the system-dependent information, can be expressed as:

$$\boldsymbol{\sigma_{\alpha\beta}(\mathcal{E})} = \frac{e^2}{N}\sum_{i,\,k} \boldsymbol{\tau_{i,k} v_{i,k}(i,k) v_{\beta}(i,k)} \frac{\delta(\varepsilon - \varepsilon i,k)}{\delta\varepsilon} \quad (3)$$

In the given expression, where *N* is the number of k-points, *i* is the band index, *k* represents the wave vector, is the relaxation time dependent on the wave vector, and $v_{\alpha}$ *(i,k)* denotes the group velocity. The group velocity, an essential parameter, can be derived from the calculation of the band structure, providing valuable information about the material's electronic transport behavior.

$$\boldsymbol{v_{\alpha}(i,\,k)} = \frac{1}{\hbar}\frac{\delta\mathcal{E}_{i,k}}{\delta k_{\alpha}} \quad (4)$$

where $\hbar$ is the Planck's constant.

## 3 RESULTS AND DISCUSSION

As shown in Table 1-5, the calculated thermoelectric figure of merit in this study surpasses the experimental values, and one plausible explanation for this disparity lies in the fact that only electronic thermal conductivity was considered in the calculations. In practice, the total thermal conductivity, encompassing both electronic and phonon contributions, would likely lead to a lower experimentally measured figure of merit. It is worth noting that, in semiconductors, the dominance of electronic thermal conductivity at high temperatures is expected to be a contributing factor to the observed trends.

**Table 1** MgS2 Structure Details

| | |
|---|---|
| Energy Above Hull | 0.005 eV/atom |
| Space Group | $Cmc2_1$ |
| Band Gap | 1.01 eV |
| Predicted Formation Energy | -1.149 eV/atom |
| Magnetic Ordering | Non-magnetic |
| Total Magnetization | 0.00 μB/f.u. |
| Experimentally Observed | No |

**Table 2** Lattice (Conventional)

| | |
|---|---|
| a | 3.94 Å |
| b | 6.82 Å |
| c | 9.15 Å |
| α | 90.00 ° |
| β | 90.00 ° |
| ɣ | 90.00 ° |

| | |
|---|---|
| Volume | 245.93 Å³ |

**Table 3** Atomic Positions

| Wyckoff | Element | x | y | z |
|---|---|---|---|---|
| 4a | Mg | 1/2 | 0.013605 | 0.722525 |
| 4a | S | 1/2 | 0.344614 | 0.858485 |
| 4a | S | 1/2 | 0.677021 | 0.585733 |

**Table 4** Symmetry

| | |
|---|---|
| Crystal System | Orthorhombic |
| Lattice System | Orthorhombic |
| Hall Number | C 2c -2 |
| International Number | 36 |
| Symbol | $Cmc2_1$ |
| Point Group | mm2 |
| Number of Atoms | 12 |
| Density | 2.39 g·cm$^{-3}$ |
| Dimensionality | 3D |
| Possible Oxidation States | $Mg^{2+}$, $S^{-}$ |

**Table 5** Chemical Environment

| Wyckoff | Species | Environment | IUPAC | CSM |
|---|---|---|---|---|
| 2a | $Mg^{2+}$ | Octahedron | OC-6 | 1.291 |

The results obtained from the computational properties, structural properties, and thermoelectric properties are explained in this section. In Figure 2 below, shown that the convergence point for the lattice is taken as 5 at a cell volume of about -328Å³, the space group is P1, the system being triclinic we have a = 3.9412 Å, b = 6.8214 Å, c = 9.1478 Å, 6 sites were used for the asymmetric unit, and it has a crystal structure type. In this section, we delve into the investigation of several thermoelectric properties specifically, electrical conductivity, thermal conductivity, Seebeck coefficient, power factor, and the thermoelectric figure of merit *(ZT)* as depicted in Figure 6. These properties are derived from the energy band gap and the electronic band structure, as thoroughly analyzed in the preceding sections. The material under scrutiny exhibits an indirect band gap that undergoes modification with temperature due to the thermal excitation of electrons and holes. From the analyzed electronic structure, including the band structure and energy density of states, we can readily derive the electrical conductivity spectrum $\sigma_{ave}$ as a function of temperature, assuming a constant relaxation time.

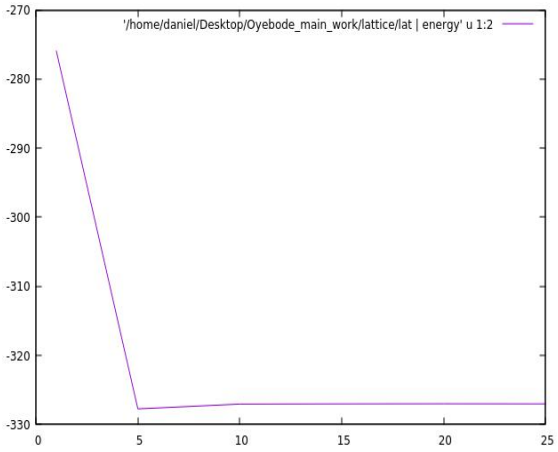


**Figure 2** Lattice constant curve of MgS2

For the following figures 3 below, kindly note that μ - $\mathcal{E}_f$ [Ha] is the temperature (T)

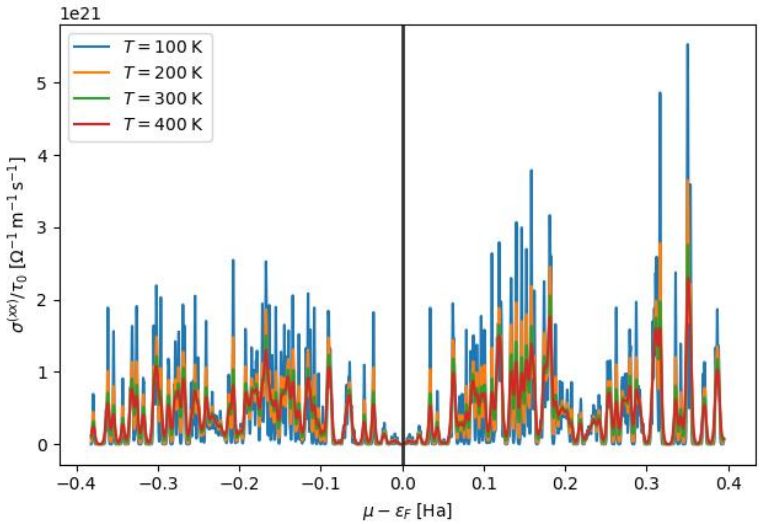


**Figure 3** Electrical Conductivity(σ) against Temperature(T)

In Figure 4 below, the temperature range of 300 to 800 K illustrates the variation in the Seebeck coefficient (S) . The (S) values exhibit sensitivity to both carrier concentration and temperature. Figure 4 strongly supports the characterization of MgS2 as a p-type semiconductor, a conclusion drawn from the position of the Fermi level concerning the top of the valence band or the bottom of the conduction band. The (S) spectrum demonstrates a notable decrease in magnitude with the temperature increasing from 100 to 400 K, reflecting the concurrent rise in carrier concentration. At 100 K, the Seebeck coefficient stands at 1.5 × 10−3 V $K^{-1}$, while at 400 K, the (S) value reduces to 5.00 × 10−4 V $K^{-1}$. Furthermore, observations from Figure 4 underscore the (S) spectrum's high sensitivity to temperature and carrier concentration variations. The reasonably dispersive nature of the energy bands around the Fermi level contributes to small effective mass values for electrons and holes. This characteristic leads to a diminished Seebeck coefficient, explaining the observed variation in its magnitude with temperature.

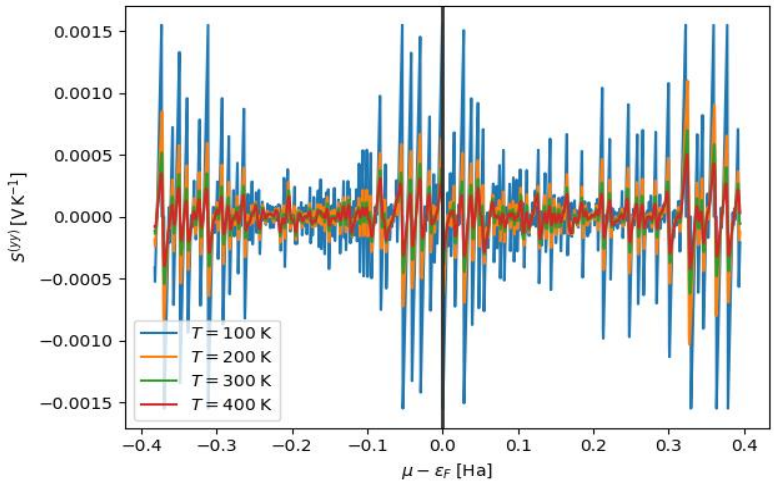


**Figure 4** Seebeck(S) against Temperature(T)

The total thermal conductivity is the sum of contributions from both lattice and electronic components, and these components exhibit distinct temperature dependencies. In our investigation, we specifically focused on the electronic component of thermal conductivity (*K*). Essentially, (*K*) is directly proportional to the carrier concentration, electrical conductivity, and mobility of charge carriers, expressed by the equation ($K = \sigma\mu_n$). For the MgS2 compound in this study, the (*K*) component is determined to be $5.0 \times 10^{15}$ W m$^{-1}$ K$^{-1}$ s$^{-1}$ at 100K and $1.5 \times 10^{16}$ W m$^{-1}$ K$^{-1}$ s$^{-1}$ at 400K. The temperature-dependent electronic thermal conductivity, as illustrated in Figure 5, exhibits a linear increase in magnitude within the temperature range of 100 K to 400 K. This observed behavior reflects the direct influence of temperature on carrier concentration, electrical conductivity, and charge carrier mobility, collectively contributing to the enhancement of (*K*) as the temperature rises.

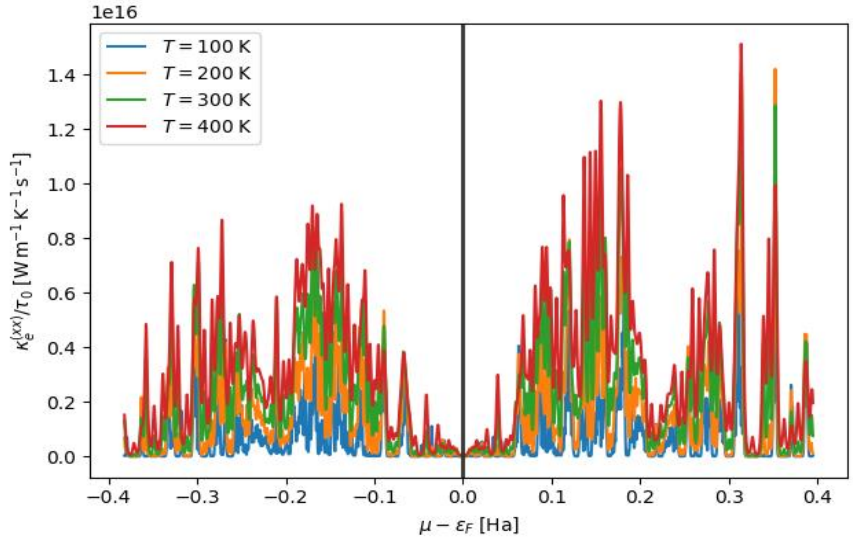


**Figure 5** Thermal Conductivity (K) against Temperature(T)

The $\sigma_{ave}$ spectrum, illustrated in Figure 6 below, reveals a linear increase in magnitude with temperature ranging from 100 to 400 K. This observed behavior in the $\sigma_{ave}$ spectrum at its maximum can be attributed to the excitation of carriers from the occupied valence band to the unoccupied conduction band at the highest temperature considered in this study (400 K). This excitation process leads to an augmented number of carrier concentrations available for electrical conduction, thereby influencing the observed increase in the electrical conductivity magnitude. Differences in volume observed in comparison to other theoretical findings could be attributed to the choice of pseudopotential[22]. The utilization of PBEsol is noteworthy as it enhances the structural characteristics of compounds in contrast to alternative pseudopotentials. This underscores the efficacy of the generalized gradient approximation (GGA) over the local density approximation (LDA), as demonstrated by [23] . After these calculations, the derived results were employed in determining the various physical properties of the investigated compounds. The power factor ($S^2\sigma$), depicted in Figure 6, is computed from the product of the Seebeck coefficient and electrical conductivity. As the temperature ascends from 100 K to 400 K, there is an increase in ($S^2\sigma$). Specifically, at low temperatures (100 K), the ($S^2\sigma$) value is $5.8 \times 10^{13}$ W m$^{-1}$ K$^{-2}$ s$^{-1}$, while at high temperatures (400 K), it reaches approximately $2.5 \times 10^{13}$ W m$^{-1}$ K$^{-2}$ s$^{-1}$. This decrease in ($S^2\sigma$) is primarily attributed to the thermally induced elevation in carrier concentration, leading to an enhancement in

electrical conductivity in semiconductors. The substantial magnitude of the ($S^2\sigma$) parameter for the MgS2 compound suggests that it may not be an ideal candidate for applications in thermoelectric devices. The observed characteristics indicate limitations in its thermoelectric potential. The thermoelectric figure of merit ($ZT = \frac{S^2\sigma T}{K}$) illustrated in Figure 7, exhibits interesting and distinctive characteristics. As the temperature undergoes an increment from 100 K to 400 K, the spectrum initially displays a linear increase, reaching its maximum value before subsequently decreasing. This trend observed consistently at each temperature within the 100 K to 400 K range, suggests a complex interplay between temperature and doping concentration. However, with further temperature increase, the magnitude of *ZT* begins a gradual descent, ultimately reaching values close to zero.

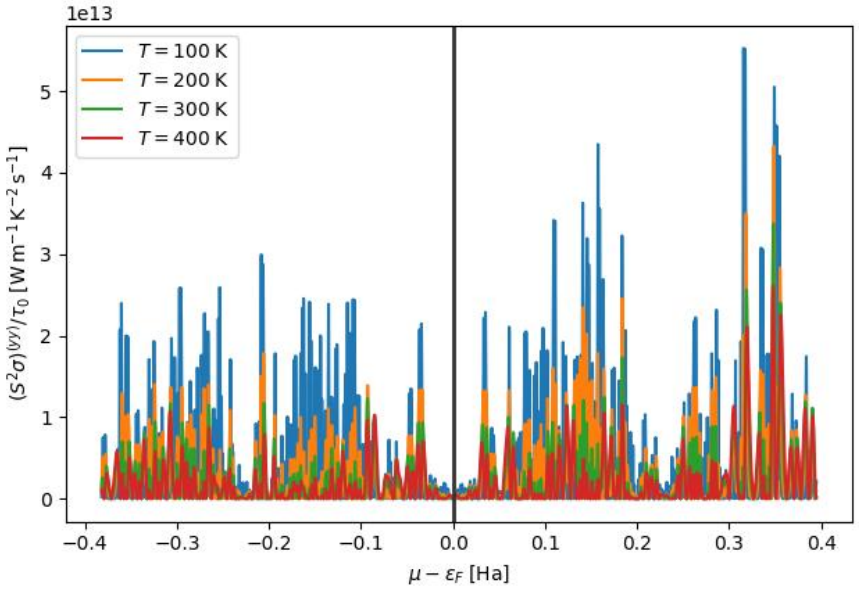


**Figure 6** Power Factor (PF) against Temperature(T)

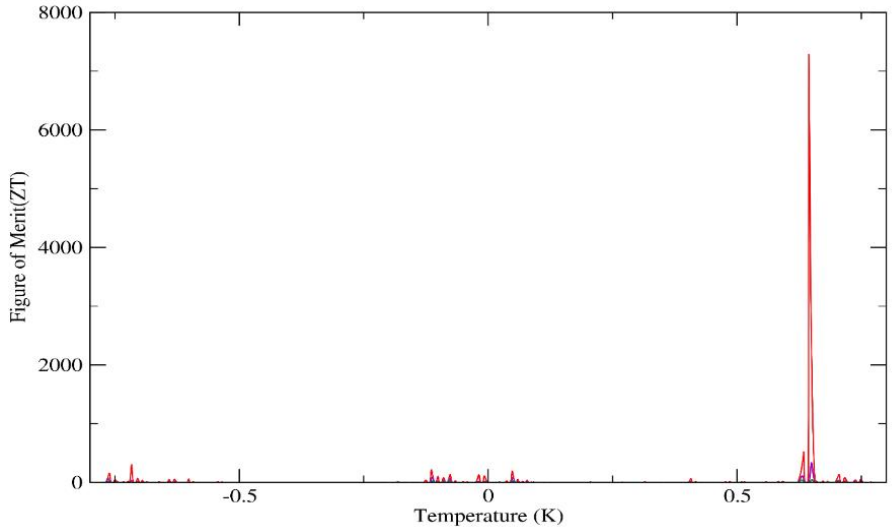


**Figure 7** Figure of Merit(ZT) against Temperature(T)

Figure 7 underscores that the *ZT* spectrum is influenced by both temperature and doping concentration. A higher *ZT* value is predominantly derived from a combination of elevated electrical conductivity and reduced thermal conductivity. The interplay between these factors contributes to the nuanced behavior observed in the *ZT* spectrum across varying temperature ranges. The findings suggest that the studied compound holds promise for applications in both cooling devices and other relevant thermoelectric applications. The significant dependence of the ($S^2\sigma$) spectrum on temperature is particularly noteworthy, representing a valuable thermoelectric property. It is important to note that the thermoelectric figure of merit presented in this study focuses solely on electronic thermal conductivity.In insulating systems, where heat is primarily conducted by phonons, the electronic contribution becomes more pronounced with increasing temperature, as demonstrated in Figure 5. In contrast, the contribution from lattice vibrations is expected to sharply decrease at higher temperatures. It should be acknowledged that the presented thermoelectric figure of merit might be somewhat overestimated, as it only considers the electronic thermal conductivity. In reality, the total thermal

conductivity encompasses both electronic and phonon thermal conductivities. This could lead to a reduction in the experimentally measured figure of merit. Notably, in semiconductors, the electronic thermal conductivity tends to increase with temperature, while the phonon thermal conductivity substantially decreases at sufficiently high temperatures (beyond the Debye temperature). Consequently, at elevated temperatures, the thermoelectric figure of merit is anticipated to be predominantly influenced by electronic thermal conductivity. The calculated thermoelectric figure of merit in this study surpasses the experimental values, and one plausible explanation for this disparity lies in the fact that only electronic thermal conductivity was considered in the calculations. In practice, the total thermal conductivity, encompassing both electronic and phonon contributions, would likely lead to a lower experimentally measured figure of merit. It is worth noting that, in semiconductors, the dominance of electronic thermal conductivity at high temperatures is expected to be a contributing factor to the observed trends.

## 4 CONCLUSION

The investigation of $MgS_2$'s electronic structure and thermoelectric properties through Density Functional Theory (DFT) calculations has provided significant insights. The compound exhibits an indirect band gap that changes with temperature, influencing its thermal conductivity, which is primarily determined by the electronic component. Notably, $MgS_2$ shows promising thermoelectric properties, highlighted by a substantial figure of merit (ZT) at elevated temperatures and a temperature-dependent power factor ($S^2\sigma$) that indicates its potential as a p-type semiconductor. While the calculated ZT values are higher than experimental results due to an overestimation that considers only electronic thermal conductivity, this underscores the need to account for all thermal conductivity components. Overall, $MgS_2$ is a promising candidate for thermoelectric applications, and further experimental studies could enhance its practical use in sustainable technologies.

## 5 RECOMMENDATIONS

The suggestions for improving our knowledge and use of $MgS_2$ in thermoelectric technology include a number of important steps. First, theoretical predictions regarding the thermoelectric characteristics of $MgS_2$ under carefully monitored laboratory settings must be verified by a thorough experimental validation procedure. Secondly, to offer a more precise estimate of the thermoelectric figure of merit (ZT), a comprehensive examination of both electronic and phonon thermal conductivities should be carried out. The properties of the material can also be optimized for particular applications by in-depth research on temperature-dependent behavior and the impacts of doping and alloying... Lastly, an environmental effect assessment and an evaluation of $MgS_2$'s practical uses in thermoelectric devices will assist guarantee its viability and sustainability in practical settings.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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# THE CONNOTATION AND FUNCTIONAL ANALYSIS OF OLDER ADULT CARE SERVICE MODELS: AN INTERPRETATIVE FRAMEWORK BASED ON GOVERNANCE MECHANISMS

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**Abstract:** Amid the ongoing restructuring of the older adult care service system, this study explores the general elements of governance mechanisms within the context of China's institutional environment. It proposes an analytical framework for older adult care service models, following the stages of initial form, institution, behavior, and post-intervention state. By clarifying the initial roles of public service agencies, families, social organizations, and enterprises within various service models, the study outlines their functional boundaries, strengths, and limitations. Additionally, using national strategies and current policies as practical foundations, and following the intervention path from institution to behavior, the study constructs a preliminary framework for the ideal network structure and form of older adult care services. This provides a reference for the subsequent development of a multi-tiered older adult care service system.
**Keywords:** Older adult care models; Governance mechanisms; Instruments; Actors; Networks

## 1 RESEARCH BACKGROUND AND PROBLEM STATEMENT

Unlike welfare policies in some social domains, which often face controversy or vague objectives, the significance and urgency of older adult care as a social issue are underscored by quantitative indicators that reflect the deepening level of population aging. Consequently, older adult care has been prioritized on the national strategic framework agenda.Public authorities recognize the long-term necessity of building and enhancing an older adult care system, a goal that enjoys broad consensus among social organizations and the general public. Historically, older adult care in China has been heavily influenced by Confucian values of filial piety and institutional norms, with traditional family-centered care dominating the social structure. However, factors such as the rising number of older adults, the implementation of the one-child framework, and increased population mobility have made traditional family care models increasingly inadequate. These models struggle to meet the comprehensive living and healthcare needs of older adults, especially those with significant functional impairments or cognitive decline. Comparative studies indicate that high dependency ratios in family structures, such as the "4-2-1" model (four grandparents, two parents, one child), place disproportionate caregiving burdens on only children and their spouses. These burdens are further exacerbated by external factors like work commitments and geographical constraints, making it difficult to balance older adult care with other social responsibilities. In response, national planning documents advocate for a comprehensive framework that includes older adult care services, long-term care systems, and service management mechanisms.

As care for older adults ascends the framework agenda, the academic community continues to debate the definitions and classifications of older adult care service models. Some scholars contend that current categorizations—distinguishing between home-based, community-based, and institutional care—fail to capture the true nature of older adult care services [1]. They advocate for a more integrated approach, suggesting that communities should unify various service platforms [2]. Meanwhile, other researchers focus on the practical differences between urban and rural care models, exploring aspects such as public-private partnerships in urban care facilities, community-based home care, long-term care insurance systems, rural "time-bank" models, embedded care, and technology-enhanced smart older adult care systems [3-5]. Motivated by national policies and the dual needs of the older adult population, diverse service models have evolved, prompting questions about their structures and effectiveness. These inquiries are crucial not only for the quality and dignity of older adult lives but also for theoretical discussions within academia. The concepts and scope of older adult care service models reflect the variety of organizational forms within the social structure, such as publicly managed care institutions, family-based care, and public-private partnerships. From a governance standpoint, these models can be dissected through elements like governance goals, tools, the nature of actors and subjects, and the potential outcomes of their actions. This study employs a governance framework from a public framework perspective to delineate the roles and functions of organizations such as public agencies, families, social groups, and enterprises within different older adult care service models. It aims to address pivotal questions about the meaning and operational effectiveness of these models, offering valuable insights for the development of a multi-tiered older adult care system.

## 2 THEORETICAL FOUNDATION AND ANALYTICAL FRAMEWORK

### 2.1 Ideal State and Its Realization Path: Governance Mechanisms and Institutional Structures

In addressing social framework issues, maximizing social welfare within budgetary constraints and available resources significantly influences the range of framework actions available to public service agencies. Williamson expanded the concept of governance mechanisms, shifting the focus from environmental and game-rule dimensions to micro-level analyses, encompassing markets, bureaucracies, and hybrid forms. Governance mechanisms involve organizational structures that producers adopt to minimize transaction costs, such as contracting for intermediate goods or services through cooperative production or outsourcing to external suppliers under conditions of incomplete contracts [6]. At the micro level, governance mechanisms emphasize institutional arrangements rather than institutional environments. The latter serves as a foundational assumption, while economic agents match transactions to governance structures within the institutional context to achieve desired economic outcomes [7].

When governance mechanisms and institutions are applied to the economic production and distribution sectors, the reduction of transaction costs becomes a key goal for organizations providing goods and services. The choices of governance mechanisms are typically aligned with this objective. However, in the social welfare framework domain, transaction cost indicators may not fully capture framework goals such as equity and justice. In the delivery of public services, framework objectives and value orientations significantly influence institutional rules and the behavior of actors, especially when addressing social welfare values that cannot be wholly realized by reducing transaction costs [8].

The overlap between governance mechanisms and institutional structures becomes apparent when abstracted from specific institutional contexts. Organizations such as markets, hierarchies, and non-profits function both as governance structures and as institutional rules. Bridging governance mechanisms with institutional structures, this study adopts a public sector management and social framework perspective. It examines the actions and tools of public service agencies, starting with a functional analysis rather than value judgments. Firstly, the ideal states achievable by various organizational forms and their preconditions are determined—for example, markets operate efficiently under conditions of perfect information, rational decision-making, and competition. Subsequently, the analysis identifies the specific institutional environment in the social welfare field. In China, welfare distribution emphasizes fairness and justice, with institutional analysis focusing on reducing transaction costs within this framework. Finally, specific institutional rules and implementation mechanisms are designed to address potential failures of various organizational forms within the institutional environment.

### 2.2 General Elements of Governance Mechanisms in Public Service Agency Leadership

Within China’s institutional environment, governance mechanisms led by public service agencies feature actors (the state and society) as both subjects and participants in governance, fostering a bidirectional interactive relationship. These mechanisms aim to create orderly outcomes through rules that guide, coordinate, incentivize, regulate, and constrain actors’ behaviors. Governance mechanisms encompass three core elements: institutional rules, actors, and their interactions [9]. It is worth noting that the nature of governance and the composition of governance systems vary significantly across countries and periods. Institutional environments strongly influence governance mechanisms, reflecting a nation or region’s historical, cultural, and socio-economic context.

### 2.3 Analytical Framework for Older Adult Care Service Models: Initial State - Institution - Behavior - Post-Intervention State

Using the timeline of China’s "Proactive Response to Population Aging" strategy as a reference, this study analyzes older adult care service models from their initial to post-intervention states. Institutional rules guide actors' behaviors and transactions at the micro level, addressing the relationship between institutional environments and governance mechanisms, while evaluating the implementation effects from a transaction cost perspective.

The elevation of aging-related framework goals to a national strategy marks a shift from traditional to modern older adult care models. The initial state refers to the transaction relationships among actors before the implementation of proactive aging measures. Policies and tools for aging responses, such as professional network entry mechanisms and incentive/constraint systems, form part of the institutional structure. These elements shape actors' participation in older adult care service networks and regulate the quantity and quality of transactions. Informal organizational rules, rooted in shared values and moral standards within communities, also influence actors' behavior, often interacting with formal rules to define boundaries within a given domain [10].

In this framework, actors are categorized into three dimensions:

(1)Individuals: Natural persons who are beneficiaries of framework or participants in its implementation.

(2)Organizations: Profit and non-profit entities, such as producer networks, expert networks, and issue networks.

(3)Public Service Agencies: Including framework communities (central agencies and ministries) and multilateral networks (framework implementation and oversight).

The attributes and behaviors of these actors influence the post-intervention states of older adult care supply. In contexts of incomplete information and contracts, actors may exhibit opportunistic behaviors, such as deception or breach of contract, driven by factors like asset specificity, transaction uncertainty, and frequency [11]. However, reputational, moral, and intrinsic value motivations can encourage adherence to or enhancement of contracts. Institutional rules, both formal and informal, collectively shape actors’ behaviors and transaction relationships, ultimately influencing the

post-intervention organizational forms. Generally, greater reciprocity and cooperation within governance mechanisms enhance the efficacy, value, and sustainability of older adult care service models (Figure 1).

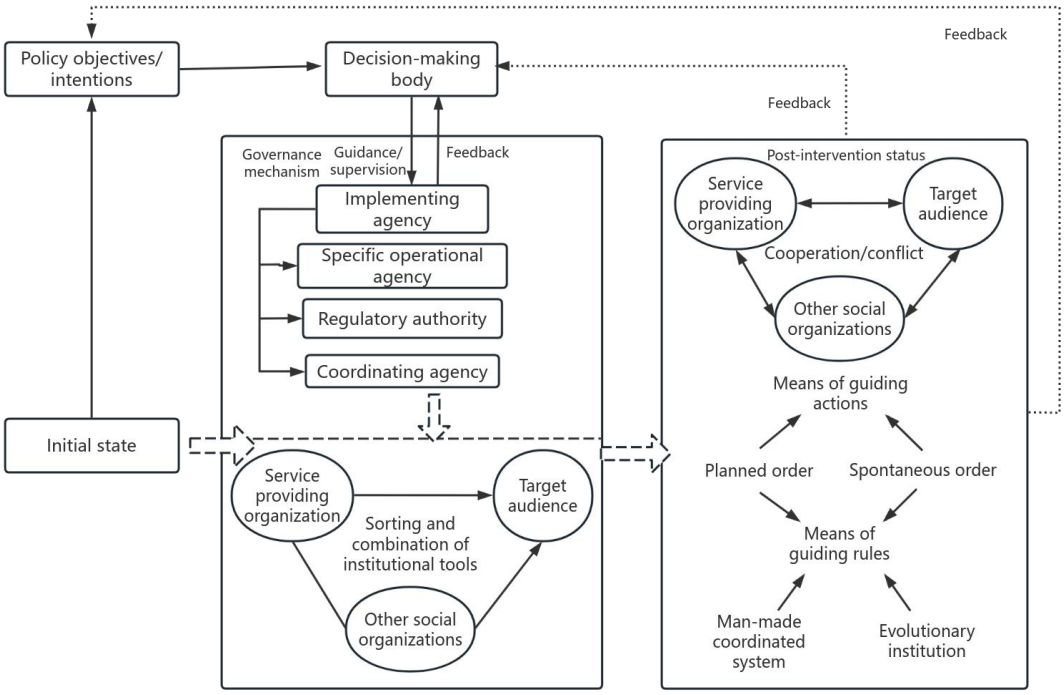


**Figure 1** Analytical Framework for Older Adult Care Service Models

## 3 FORMS OF OLDER ADULT CARE: FAMILY-BASED AND EXTERNAL PROVISION MODELS

### 3.1 Diminished Family-Based Care Capacity under Social and Demographic Transitions

Despite the deeply rooted cultural values of respecting and supporting older family members, which are intrinsic to Chinese civilization, the traditional family-centered care model is increasingly challenged by the pressures of societal and demographic transformations [12].

The first tension lies between caregiving capacity and the willingness to provide care. Data from population censuses and sampling surveys reveal a trend toward smaller and simpler family structures. From 1982 to 2010, the proportion of extended families spanning three or more generations remained below 20%, while nuclear families became more prevalent. Structurally, this shift has weakened families' ability to provide older adult care [13]. Middle-aged couples, particularly in single-child families, face significant challenges in balancing caregiving duties with work obligations due to these structural changes. Geographically, the growing scale of population mobility—evidenced by the 370 million people identified as migrants in China's seventh population census—adds another layer of difficulty. Migrant workers, often living far from their parents, encounter barriers such as time constraints and institutional challenges related to the social security and household registration systems. Even with strong caregiving intentions, families are often constrained by these systemic limitations.

The second tension arises from intergenerational cognitive gaps. The discrepancy in understanding between middle-aged and older family members, compounded by a lack of professional caregiving knowledge, may lead to neglect of the older adult's specific needs. For example, older adults often experience cognitive and memory decline, reduced logical reasoning, and slower problem-solving abilities, leading to changes in intellect, personality, emotions, and operational skills [14].

Moreover, life-course experiences uniquely shape individual cognitive patterns in old age, yet these nuances are frequently overlooked in family care interactions. The resulting cognitive dissonance may extend to a societal mismatch between the perceived and actual needs of older adults, such as focusing exclusively on basic care and medical needs while neglecting mental well-being, social engagement, or self-actualization for healthier older adults.

### 3.2 External Providers of Older Adult Care: Market, Public, and Non-Public Organizations

Surveys indicate that the majority of older adults in China prefer home-based care, reflecting societal resistance to institutional care, which is often viewed as morally less acceptable [15-16]. As a result, even when external care is needed, its acceptance remains low among the public.

External older adult care models are diverse, falling into three main categories: market-based, public, and non-public providers. Emerging hybrid models—such as public-private partnerships, community-based initiatives, and integrated medical and older adult care systems—are expanding the traditional landscape. Examples include social welfare centers, wellness programs driven by real estate and insurance initiatives, and rural mutual assistance networks.

### 3.3 Balancing Goals and Tools: Achieving Public Welfare in Older Adult Care

Each organizational model serves as a specific institutional tool. However, the gap between theoretical assumptions and practical implementation often results in unmet framework goals.

The first challenge arises from the intrinsic strengths and limitations of each institutional tool [17]. Market-driven care improves resource allocation efficiency and fosters industry development but often suffers from high costs, remote locations, inadequate facilities, and uneven service quality. Additionally, market providers are at risk of opportunistic behavior due to asset specificity, such as investments in real estate, which exacerbates information asymmetries within the sector.

In contrast, public institutions prioritize public welfare, benefiting from centralized decision-making, resource allocation, and relatively lower costs. Many public older adult care institutions, integrated into urban development projects, are well-located and have stable funding. However, financial constraints and excessive demand often result in resource shortages, leaving public services insufficient to meet broader needs.

Non-public organizations, though flexible and rooted in communities, face challenges in sustainability due to limited resources, funding, and personnel. Over time, these organizations may shift towards more profit-driven models, diluting their original public welfare mission. Family care remains constrained by its diminishing capacity, and legal mechanisms to address neglect or abuse are often insufficient due to the private nature of family interactions.

The second challenge concerns the inherent conflicts between institutional goals and the limitations of single-tool approaches. For example, while public institutions are the most reliable in ensuring public welfare, mismatched supply and demand for services leave many older adults underserved. Similarly, rising affluence has driven demand for high-end older adult care facilities primarily operated by private enterprises. Balancing these diverse needs requires strategic planning, regulatory oversight, and industry optimization to meet both basic and specialized older adult care demands.

## 4 FUNCTIONAL INTEGRATION AND EXPANSION IN MULTIFORM ORGANIZATIONAL STRUCTURES: INTERMEDIATE MODELS BETWEEN PUBLIC INSTITUTIONS AND THE MARKET

In alignment with theoretical research, the national strategy for proactively addressing population aging emphasizes the establishment of an older adult care system that is home-based, community-supported, institutionally supplemented, and integrates medical and caregiving services. This framework aims to restore the caregiving functions of families through macro-level public policies and supportive social environments [18]. Under this strategic decision, traditional actors in older adult care are integrated with newly emerging ones into a unified system. By leveraging institutional rules and cultural values, the system seeks to achieve an optimal alignment between collective ideals and individual rationality. This section will analyze the elements of the older adult care service network shaped by multiple organizational forms, as outlined in framework documents issued by the State Council and relevant departments (Figure 2).

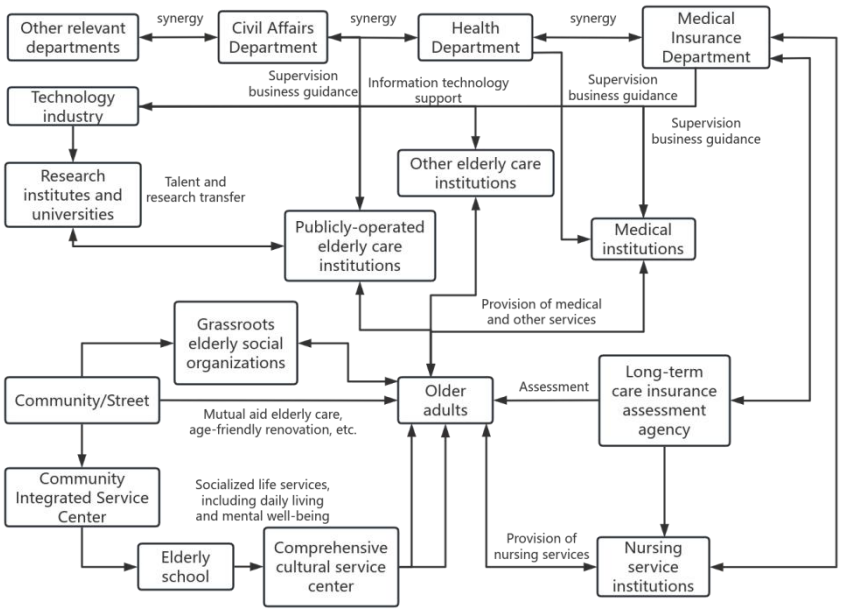


**Figure 2** Integration of Older Adult Care Service Models-An Idealized Framework

### 4.1 Expanding Access Mechanisms

The number and nature of actors integrated into the older adult care system significantly influence its operational model and effectiveness. Compared with the limited scope of earlier single-department initiatives, the current approach broadens access for both service providers and older adults. For instance, differentiated service provision is now tailored to various older adult groups, including healthy, fully independent individuals; those with chronic diseases but capable of self-care; individuals seeking higher-quality care; and those requiring home-based or institutional care due to disabilities or cognitive impairments.

In terms of service provision, traditional models involving public or for-profit enterprises are undergoing transformation. Public older adult care institutions are being restructured into enterprises or operated through public-private partnerships, with private entities encouraged to participate through sole proprietorships, joint ventures, and other collaborative formats. Framework incentives for private older adult care institutions include support in financing, taxation, land use, and personnel development. Under the ongoing reform of deregulation in the older adult care sector, private capital and social actors are granted easier access to establish care facilities. Models such as franchising, public service procurement, and public-private partnerships are supported, alongside the repurposing of existing urban infrastructure—such as vacant factories and commercial properties—for older adult care.

In parallel, healthcare services have been comprehensively integrated into older adult care provision. Institutions at all levels now assume responsibilities for health promotion, medical care, nursing, and rehabilitation. Furthermore, grassroots organizations, such as street offices and rural collectives, are playing a growing role. These entities facilitate cultural and recreational activities, support volunteer-driven initiatives, and aim to establish fitness and recreational hubs for older adults in at least 90% of urban and rural communities by 2020.

### 4.2 Rules and Reciprocity in Transactional Relationships

Expanding access and increasing actors necessitate the establishment of collaborative frameworks to ensure system coordination. Compared with prior regulatory systems in older adult care, the current framework emphasizes two critical relationships to mitigate contractual incompleteness in the older adult care market.

Firstly, the relationship between regulatory mechanisms under public institutions and market-driven mechanisms is paramount. Older adult care institutions, characterized by high investment costs, long construction cycles, and specialized assets, are prone to opportunistic behaviors without regulatory oversight, particularly given the vulnerability of older adult service recipients. To address this, regulatory frameworks are meticulously designed, covering aspects such as service quality, resource allocation, and operational standards. A localized approval and oversight principle ensures comprehensive regulation across various entities, including institutional and home-based care providers.

Secondly, the expansion of family-centered care networks underscores closer integration between families and communities. Recognizing the challenges faced by families in meeting older adult care demands, efforts are underway to enhance the coverage of family-doctor agreements through grassroots healthcare institutions. Incentive mechanisms encourage village doctors and healthcare professionals to practice in integrated care settings, with equal recognition in professional evaluations. Community-based models leverage existing infrastructure—such as rural service centers, cultural hubs, and vacant urban spaces—to meet the diverse needs of older adults, including daily living, dining, and recreational activities.

### 4.3 Embedding and Strengthening Mainstream Cultural Values

As a non-monetary institutional tool, cultural and moral education plays an increasingly pivotal role in promoting older adult care. Public institutions and communities have recognized the importance of informal evolutionary institutions in fostering cooperative relationships among actors. Efforts to instill traditional values, such as respect for older adults, are most evident during major cultural festivals like the Spring Festival, Qingming Festival, Mid-Autumn Festival, and Double Ninth Festival.

Notably, the introduction of monetary attributes into promotional activities—such as the "Respect for Older Adults Month" and awards for exemplary older adult care—reflects an evolution in framework design. Initiatives include subsidies for non-local older adult residents to access the same benefits as locals, reinforcing respect for older adults as a societal virtue. The ultimate goal is to embed these values into formal institutional rules, fostering widespread recognition and collective action among diverse actors.

## 5 DISCUSSION AND CONCLUSION

### 5.1 Integrated Governance Mechanisms: Innovations in Older Adult Care Systems and Models

The proposed strategy to actively address population aging represents a paradigm shift from traditional family-based, community-based, or institution-based models. A macro-level perspective is necessary to understand how diverse actors can form cooperative, rather than adversarial, relationships, thereby reinforcing positive feedback mechanisms within

the older adult care system. Instead of relying solely on single-provider models, the continuation of the older adult care framework hinges on institutional innovation in framework implementation at the local level.

### 5.2 Further Exploration of Institutional Tools and Actor Theories in Governance Mechanisms

Given the lack of participatory research and the relatively recent introduction of aging-related policies, the discussions presented here remain preliminary, blending theoretical insights with framework and practice. Further research could address questions such as: What motivates local public institutions to design specific regulations based on regional economic and cultural contexts? How do operational departments implement these regulations? How do actors respond to institutional tools, and to what extent do these tools align with framework goals and cultural values? Comparative studies of governance mechanisms and longitudinal analyses of framework impacts could provide valuable insights into optimizing older adult care systems.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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# HYDRAULIC IMBALANCE IN HEATING SYSTEMS PROBLEM ANALYSIS

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**Abstract:** This paper focuses on four main research topics related to hydraulic balance of heating system, including the causes of hydraulic imbalance, the adjustment method of hydraulic balance, the influence of hydraulic balance on the economic benefits of heating system, and the relationship between operation optimization of heating system and hydraulic balance. This paper analyzes the research questions, controversial views, and research deficiencies under each topic, and lists relevant cases, aiming to comprehensively sort out the research status in this field and provide reference for further research.
**Keywords:** Hydraulic equilibrium; Heating systems; Modulation methods; Optimize your operation

## 1 INTRODUCTION

With the progress of China's society and technology, the centralized heating network industry has developed rapidly.The quality requirements are getting higher and higher, but at this stage, there is still a serious injustice between the development of China's central heating industry and people's needs balance mismatch problem [1]. The hydraulic balance of the heating system is of great importance to ensure the quality of heating, improve energy efficiency and reduce operating costs. However, in the actual heating project, the problem of hydraulic balance is complex and diverse, involving many aspects of research. Several key research themes are analyzed in detail below.

## 2 CAUSES OF HYDRAULIC IMBALANCE

### 2.1 Research Questions

Hydraulic unbalance is a common problem in Chinese district heating (DH) systems. Hydraulic unbalance has resulted in poor flow distribution among heating branches and overheating of apartments. Studies show that nearly 30% of the total heat supply is being wasted in Chinese DH systems due to a lack of pressure and flow control[2].The causes of hydraulic imbalance in heating systems are manifold. At the design level, the unreasonable design of the pipe network is an important factor. If the pipe diameter is too small, the water flow speed will be accelerated, and the resistance along the route and local resistance will increase significantly, which will easily cause excess user flow at the near end and insufficient flow at the far end. On the contrary, if the pipe diameter is too large, the flow rate will be too low, which is not conducive to the stable operation of the system. The unreasonable direction of the pipeline, such as the existence of too many elbows, tees and other complex pipe fittings, will also increase the local resistance and destroy the hydraulic balance. In terms of terminal equipment design, improper selection of radiator model, mismatch of resistance characteristics with the system, or unreasonable installation location affecting thermal cycling may cause hydraulic imbalance. In the design of the control system, the selection of the control valve is unreasonable, such as the flow characteristics of the control valve do not meet the system requirements, or the control strategy does not consider the differences in the needs of different users, which will also have a negative impact on the hydraulic balance.
In terms of operation management, unreasonable heating parameters are a common problem. If the water supply temperature is too high or the pressure is too high, the flow rate of the proximal user will exceed the design value, and the flow rate of the remote user will decrease. Unreasonable heating scheduling, such as failure to adjust the distribution of heating load in time according to outdoor temperature changes, can also lead to hydraulic imbalance. Inadequate maintenance, such as fouling in the pipeline and valve damage, will increase the system resistance and affect the hydraulic working conditions.
The influence of the user's thermal behavior on the hydraulic balance cannot be ignored. If the user modifies the heating equipment without permission, such as increasing the number of radiator pieces or changing the pipe connection method, the local resistance characteristics will be changed. Arbitrary adjustment of the heating valve, especially over-regulation or closing of the valve, can upset the hydraulic balance of the entire system. External factors also play a significant role. Temperature changes can change the heat load demand of a building, which in turn affects the hydraulic condition of the heating system. Changes in the groundwater level may create buoyancy or pressure on buried pipelines, affecting the normal operation of pipelines and leading to hydraulic imbalances.

### 2.2 Disputed Views

There are different views on the importance of the causes of hydraulic imbalance. Some scholars emphasize the leading

role of the design stage, believing that as long as various hydraulic factors are fully considered in the design process, and the design is carried out in strict accordance with the specifications and accurate calculations, most of the hydraulic imbalance problems can be fundamentally avoided. They believe that although the follow-up operation management and external factors have an impact, they are relatively secondary, and can be dealt with by reserving a certain amount of adjustment margin through reasonable design. However, other scholars have pointed out that in actual operation, operation management and user behavior factors often have a more prominent impact on hydraulic imbalance. Because it is difficult to predict all the actual operating conditions completely and accurately during the design stage, such as changes in occupancy rates of users, differences in users' heating habits, etc. Moreover, even if the design is reasonable, poor operation management during long-term operation, such as failure to repair and adjust in time, will gradually lead to hydraulic imbalance.

### 2.3 Insufficient Research

The current research is still insufficient to quantify the specific contribution of different causes to hydraulic imbalance. Although it has been established that various factors can cause hydraulic imbalances, the weight of each factor that causes imbalances in a particular heating system has not yet been established. For example, for a specific district heating system, it is difficult to accurately determine the proportion of design factors, user behavior factors, etc., which makes it difficult to formulate targeted prevention and solution measures. The difficulty of this quantitative study lies in the complexity of the heating system, which involves the interaction of many factors and the characteristics of different systems are quite different.

The long-term and dynamic effects of user thermal behavior and external factors are not well studied. Taking the user's heat use behavior as an example, although it is known that the user's unauthorized modification and other behaviors will affect the hydraulic balance, there is a lack of in-depth research on the law of the user's heat use behavior with the season and socio-economic factors. For example, the frequency and magnitude of the valve adjustment may vary from season to season, and it is not fully understood how this variation relates to the hydraulic imbalance in the heating system. For external factors, the long-term mechanism of action under different geological and climatic conditions also needs to be further explored. For example, in the case of large seasonal changes in groundwater level in coastal areas, the long-term impact model on the hydraulic balance of heating pipe networks needs to be studied more deeply.

## 3 ADJUSTMENT METHOD OF HYDRAULIC BALANCE

### 3.1 Research Questions

When it comes to static hydraulic balancing regulation, accurate selection and installation of static hydraulic balancing equipment is key. Static hydraulic imbalance is due to the design, construction, and pipe quality of the pipe network system, resulting in the ratio of the pipeline resistance coefficient being different from the ratio of the pipeline resistance coefficient required by the design, so that the flow of the secondary pipe network cannot be reasonably distributed according to the design value, resulting in the hydraulic imbalance of the secondary network [3]. For example, the selection of static hydraulic balancing valves is based on the flow rate, differential pressure and other parameters of the system. Selecting the right valve type (e.g., equal percentage, straight, etc.) requires an in-depth understanding of the hydraulic characteristics of the system. During installation, the position and orientation of the valve and the way it is connected to the surrounding pipes all affect its adjustment effect. Determining whether the system has reached static hydraulic equilibrium requires a suitable detection method, such as measuring the flow rate and differential pressure of each branch and comparing the design values.

For dynamic hydraulic balance adjustment, the working principle of various types of dynamic hydraulic balance equipment is quite different. The dynamic flow balancing valve maintains the set flow rate by automatically adjusting its own opening, which is not affected by system pressure fluctuations; The dynamic differential pressure balancing valve keeps the differential pressure at both ends of the valve constant. Automatic adjustment relies on advanced sensors and control systems. Sensors monitor the water flow in the system and relay real-time data to the control system, which then adjusts to preset parameters [4]. Understanding the scenarios in which these devices are suitable is essential for effectively adjusting the hydraulic balance. In a complex heating pipe network, the needs of different regions and different users are different, and a variety of adjustment methods need to be used comprehensively. For example, for areas with uneven distribution of heat users and large changes in heat load, it may be necessary to combine static and dynamic adjustment methods, while considering the characteristics of different branches for targeted adjustment.

### 3.2 Disputed Views

In the choice of adjustment method, there is a controversy between traditional method and intelligent method. Some researchers believe that traditional mechanical adjustment methods, such as control valve adjustment, have the advantages of mature technology and high reliability. Control valves have a long history of use in heating systems, and operators are familiar with their regulation methods, and their costs are relatively low. However, another group of researchers is more inclined to intelligent adjustment methods, such as AI-based adjustment systems. This kind of system can automatically adjust the parameters of the adjustment equipment according to the real-time monitoring data (such as temperature, flow, pressure, etc.), with high adjustment accuracy and strong adaptability. For example, the

hydraulic change trend of the heating system can be predicted and adjusted in advance through the neural network algorithm, but the cost of this method is high, and the current technology is not mature enough, and there are problems such as poor adaptability to complex environments and the accuracy of the algorithm needs to be improved.

### 3.3 Insufficient Research

There is a lack of unified evaluation standards for the comprehensive regulation effect of complex heating pipe networks. Unfortunately, to the authors' knowledge, there are no long-term field studies demonstrating the level of energy savings achieved in engineering practice with commonly used valves, such as thermostatic radiator valves (TRV), differential pressure control valves under risers (DPCV), pressure-independent balanced radiator valves (PIBRV), and their combinations[5]. For complex heating networks, it is difficult to accurately measure and compare the effects of different combinations of adjustment methods in practical applications. For example, in a large urban heating network, a static balancing valve, a dynamic flow balancing valve and an intelligent control system are used for hydraulic regulation at the same time, it is difficult to determine whether this regulation scheme is optimal, and it is difficult to judge whether the regulation effect in different areas meets expectations due to the lack of unified evaluation criteria. This leads to great difficulties in selecting the optimal accommodation regimen, often relying on empirical or local experimentation.

There is insufficient research on the long-term compatibility between new intelligent regulation equipment and traditional regulation equipment in the actual heating system. In the process of upgrading and renovating heating systems, it is common for old and new equipment to be mixed. For example, in the renovation of some old heating systems, some of the original control valves may be retained, and new intelligent balance valves may be installed. However, there is little research on the problems that may arise when the old and new equipment is mixed, such as control signal interference, the effect of hydraulic coupling between different devices, etc., and how to optimize their interoperability. This can lead to equipment failures or poor regulation in actual operation.

## 4 THE INFLUENCE OF HYDRAULIC BALANCE ON THE ECONOMIC BENEFITS OF HEATING SYSTEM

### 4.1 Research Questions

Hydraulic balance regulation has an important impact on the energy consumption of heating systems. By adjusting the hydraulic balance, the flow distribution of each user can be more reasonable, and the phenomenon of overheating and overcooling of some users can be avoided, thereby reducing energy waste. But how to quantify this energy saving effect is a key question. For example, it is necessary to determine how much energy consumption per unit area of heating is reduced by means of hydraulic balance adjustment, as well as the proportion of the total energy consumption of the entire heating system.

The improvement of heating quality can bring significant economic benefits. Energy consumption management is an inevitable choice for the current central heating enterprises to meet the development of the times, and it is also the only way for the country to advocate energy conservation and consumption reduction. Central heating enterprises should conduct in-depth analysis of the current problems, improve the quality of heating and reduce energy consumption by upgrading heating equipment and optimizing the design of heating systems, actively respond to the call of the state, and at the same time achieve the sustainable development of central heating enterprises [6]. Reducing user complaints and improving user satisfaction are important aspects. For example, increased user satisfaction may reduce economic losses such as refunds due to heating problems, while also benefiting the reputation and market competitiveness of heating companies. Evaluating these values requires appropriate methods, such as user surveys, complaint rate statistics, etc., to quantify the impact of changes in user satisfaction on economic benefits.

From the perspective of extending the life of the equipment and reducing the maintenance cost, the hydraulic balance adjustment makes the equipment operate under more reasonable working conditions. For example, a reasonable flow rate and pressure can reduce wear and tear on equipment such as water pumps, reducing the frequency and cost of maintenance. However, it is necessary to accurately calculate how much the life of the equipment is extended before and after the hydraulic balance adjustment, and how much the maintenance cost is reduced.

### 4.2 Disputed Views

There are differences among different researchers regarding the quantitative evaluation of economic benefits. Some researchers believe that the existing evaluation methods are too simplistic, only considering the direct energy saving and some cost reduction factors, and cannot fully reflect the comprehensive economic benefits brought by hydraulic balance regulation. For example, existing approaches may ignore the assessment of the long-term market benefits of increased user satisfaction. However, other researchers believe that in practice, it is difficult to obtain all relevant data accurately, and that overly complex evaluation methods are not practical. For example, it is difficult to accurately assess the impact of user satisfaction on a company's long-term market share, as it is interfered with by a variety of market factors.

### 4.3 Insufficient Research

There is no well-established model to evaluate the economic benefits of hydraulic balance from the perspective of the whole life cycle. Most of the existing evaluations focus on short-term energy savings and partial cost reductions, and lack comprehensive consideration of the economic benefits of hydraulic balance in the whole life cycle of the heating system, including equipment renewal and technology upgrading. For example, in the 10-20 years of operation of the heating system, with the aging of equipment and technological upgrading, the influence of hydraulic balance regulation on economic benefits at different stages is not fully understood.

There is a gap in the comprehensive evaluation of social benefits (such as the impact on the environment, the promotion of urban heating stability to social development, etc.) and economic benefits. Hydraulic balance regulation not only affects the economic benefits of heating enterprises, but also has a wide impact on society. For example, a good hydraulic balance can reduce energy consumption and, in turn, carbon emissions, which is good for the environment. At the same time, stable heat supply is very important for the life of urban residents and the normal operation of cities, but there is a lack of research on the unified quantitative analysis of these factors, and it is difficult to comprehensively evaluate the comprehensive value of hydraulic balance regulation.

## 5 THE RELATIONSHIP BETWEEN THE OPERATION OPTIMIZATION OF THE HEATING SYSTEM AND THE HYDRAULIC BALANCE

### 5.1 Research Questions

Optimizing the operating parameters of the heating system is essential to achieve hydraulic balance under different operating conditions. For example, under different outdoor temperature conditions, the heat load will change, and parameters such as water supply temperature, flow rate, etc., need to be adjusted accordingly. In the early and late cold periods when the heating load is low, the hydraulic balance can be maintained by appropriately reducing the water supply temperature and flow. In severe cold periods, heating parameters need to be improved. At the same time, different heating load distributions, such as changes in user occupancy rates, differences in heat demand in different regions, etc., also need to adjust the operating parameters to ensure hydraulic balance.

Hydraulic balance regulation has an important impact on the stability and reliability of the heating system. Reasonable hydraulic balance can avoid equipment failures caused by excessive or small local flow, such as pump overload, pipeline rupture, etc., and improve the stability of the system. At the same time, the stable hydraulic balance can ensure the heating quality of each user, reduce the system failure caused by heating problems, and improve reliability. The focus of research is how to further improve the overall operational performance of the system by optimizing the hydraulic balance, such as dynamically adjusting the hydraulic balancing equipment to adapt to changes in the system.

The application of intelligent technology in the operation optimization and hydraulic balance adjustment of heating system has broad prospects, but it also faces challenges. Intelligent technology can monitor the temperature, pressure, flow and other parameters of the system in real time, and automatically adjust the operating parameters and hydraulic balancing equipment through the control algorithm. However, it faces problems such as sensor accuracy, control algorithm accuracy, and system compatibility. For example, measurement errors in sensors can lead to incorrect control decisions that affect the effectiveness of hydraulic balancing.

### 5.2 Disputed Views

There are different views on the application of intelligent technology. Some scholars believe that intelligent technology is an inevitable trend in the future operation optimization and hydraulic balance adjustment of heating systems, and should be vigorously promoted and applied. They believe that intelligent technology can improve the accuracy and efficiency of adjustment, and better adapt to complex and changeable operating conditions. For example,The results show that compared with the traditional centralized computing method, the optimal control method under the distributed architecture can solve the problem of on-demand heating of the secondary pipe network in the district heating system under the fast convergence speed, and the energy consumption of transmission and distribution are low[7]. An intelligent control system based on big data and artificial intelligence can predict system changes based on historical data and real-time data, and make optimization adjustments in advance. However, other scholars believe that intelligent technology is not suitable for large-scale application due to its high cost and difficulty in retrofitting some old heating systems. They advocate starting with traditional operational optimization methods and gradually improving and upgrading. For example, for some areas with poor economic conditions and aging heating systems, the large-scale installation of intelligent equipment may increase the burden on enterprises, and may lead to operational problems due to the unskilled operation of new equipment by technicians.

### 5.3 Insufficient Research

There is insufficient research on the intelligent operation optimization and hydraulic balance adjustment strategies of different types and scales of heating systems under complex working conditions (such as extreme weather, sudden heating failure, etc.). Most of the existing studies focus on conventional working conditions, and there is a lack of in-depth discussion on coping strategies for special situations. For example, in the event of extreme cold weather, the heat load of the heating system increases sharply, and how to quickly adjust the hydraulic balance and operating parameters to ensure heat supply through intelligent technology is rarely studied. For sudden heating failures, such as

pipeline leakage, pump failure, etc., the research on how to adjust the hydraulic balance in time to reduce the impact of the failure is also not perfect.

In the study of the application of intelligent technology, there is not enough research on its adaptability with the existing operation management system and personnel skill level. Intelligent systems need appropriate management and operation, but there is a lack of research on how to adapt the existing personnel and management mode of heating enterprises to intelligent regulation. For example, the maintenance of intelligent systems requires professional technicians, but heating companies may lack relevant talents. At the same time, the existing operation management system may not adapt to the real-time monitoring and rapid decision-making requirements of intelligent systems, and corresponding reforms need to be carried out, but the research in this area is still relatively weak.

## 6 CONCLUSION

The research on hydraulic balance of heating system has achieved certain results in many aspects, but there are still obvious research gaps. In terms of the causes of hydraulic imbalance, it is necessary to strengthen quantitative analysis and long-term dynamic research on complex influencing factors. For the hydraulic balance adjustment method, a unified evaluation standard should be established and the compatibility of the old and new equipment should be studied in depth. In the evaluation of the economic benefits of hydraulic balance, it is necessary to improve the whole life cycle model and comprehensively consider the social benefits. The research on the relationship between heating system operation optimization and hydraulic balance needs to be extended to complex working conditions and pay attention to the adaptability of intelligent technology. Through further in-depth study of these aspects, it is expected to improve the hydraulic balance level of the heating system, improve the quality and economic benefits of heating supply, and promote the sustainable development of the heating industry.

More interdisciplinary research methods and technological innovations are needed to fill the current research gap and provide more scientific guidance for the optimal design, operation and management of heating systems. Future research can be combined with computer simulation, big data analysis, intelligent technology and other means to further explore the hydraulic balance of heating system to meet the increasing demand for heating and energy efficiency.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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# INNOVATION AND PRACTICE IN PRODUCT DESIGN TEACHING DRIVEN BY INTELLIGENT TECHNOLOGY

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**Abstract:** With the rapid development of intelligent technology, its application in the field of education is becoming increasingly widespread. This article aims to explore the innovative application and practical effects of intelligent technology in product design teaching. The article first analyzes the impact of intelligent technology on educational models, then elaborates on the specific applications of intelligent technology in product design teaching, including the intelligent updating of teaching content, the innovation of teaching methods, and the improvement of teaching evaluation systems. It discusses how to introduce the concept of "Artificial Intelligence + Design" to build a cutting-edge teaching framework and adopt case-based teaching methods to enhance students' innovation and practical abilities. Through case analysis, this article demonstrates the effectiveness of intelligent technology in actual teaching and discusses the challenges it faces. Finally, the article proposes suggestions and prospects for the future application of intelligent technology in product design teaching.
**Keywords:** Intelligent technology; Product design; Teaching innovation; Practical application; Artificial intelligence

## 1 INTRODUCTION

With the rise of artificial intelligence, big data, cloud computing, and other intelligent technologies, the education industry is undergoing unprecedented changes. Especially in the field of product design, the application of these technologies has not only changed design tools and methods but also put forward new requirements for the training of designers. Traditional design education faces challenges in integrating new technologies, updating teaching content and methods. Therefore, studying how intelligent technology drives innovation and practice in product design teaching is of great significance for improving teaching quality and cultivating innovative talents.

This study aims to explore the current status and development trends of intelligent technology application in product design teaching, analyze its innovation points in teaching content, methods, and evaluation systems, propose a teaching model that combines the concept of "Artificial Intelligence + Design", and verify its effectiveness through practical cases. At the same time, this study will also explore problems encountered during implementation and solutions, providing references for future teaching reforms. This article uses a combination of literature review, case analysis, and empirical research methods. Firstly, it summarizes the application of intelligent technology in the field of education through literature review; secondly, it selects typical teaching cases for in-depth analysis; finally, based on empirical data, it evaluates the actual effects of intelligent technology in product design teaching and proposes corresponding suggestions.

## 2 CURRENT STATUS AND CHALLENGES OF PRODUCT DESIGN TEACHING

Traditional product design teaching mainly relies on a combination of teacher lectures and student practice, focusing on basic skill training. In this mode, the teaching content is relatively fixed, making it difficult to adapt to rapidly changing market demands and technological development. Currently, product design teaching faces issues such as outdated teaching content, limited practical opportunities, and insufficient cultivation of innovative abilities. These problems limit the enhancement of students' design thinking and practical operation capabilities.

The introduction of intelligent technology provides new ideas for solving the above problems. For example, virtual reality technology can simulate real design environments, enhancing students' practical experience; using big data analytics can help teachers better understand students' learning progress and needs, achieving personalized teaching. Currently, the application of intelligent technology in the field of education mainly focuses on intelligent teaching systems, virtual laboratories, online courses, etc. These applications not only enrich teaching methods but also provide students with more flexible and diverse learning methods. However, how to effectively integrate these technologies into traditional teaching systems remains a question worth exploring.

## 3 INNOVATION IN PRODUCT DESIGN TEACHING DRIVEN BY INTELLIGENT TECHNOLOGY

Intelligent technology refers to the use of multidisciplinary knowledge such as computer science and cognitive science to simulate human intelligence behavior. AI can provide design inspiration through data mining and pattern recognition, optimize design schemes, and even predict market trends. From early expert systems to deep learning today, intelligent technology has undergone multiple stages of development and has shown great potential in various fields. In the field of education, intelligent technology is used in personalized learning, intelligent tutoring, automated evaluation, etc.,

greatly improving teaching efficiency and quality.[1] To respond to the national strategy for artificial intelligence and the Ministry of Education's call for construction and development related to artificial intelligence, in 2018, Microsoft Research Asia collaborated with four top Chinese universities—Peking University, University of Science and Technology of China, Xi'an Jiaotong University, and Zhejiang University—to create a new generation of open scientific research and education platforms for artificial intelligence. This platform launched the country's first open-source platform solution in the field of deep learning developed jointly by multiple parties—Open Platform for AI (Open PAI), aiming to establish an independent intellectual property rights and innovative achievements foundation support platform for artificial intelligence.

The launch of the Open PAI platform marks an important step in China's education and research work in the field of artificial intelligence. Leveraging its open, open-source, compatible characteristics, combined with Microsoft's powerful computing capabilities and resources, the platform provides strong technical support for cooperating universities. Through this platform, universities can enjoy advanced artificial intelligence management and scheduling services while also exploring innovation and educational services in the field of artificial intelligence. Open PAI not only provides an integrated development environment for the entire lifecycle—Tools For AI, but also integrates Microsoft's open-source tools in core technology areas such as speech, vision, language, as well as high-quality open-source tools from universities in their respective fields. Such an integrated development environment significantly reduces the cost of learning and research, allowing teachers and students to more flexibly apply core technologies to solve key industry problems, thereby enhancing the value and influence of scientific research achievements.

Over the past seven years, Zhixin Platform has provided Chinese universities with four core resources and services, including computing platforms, algorithms and tools, data, and courses. These resources and services not only support the development of joint scientific research projects but also promote various forms of cooperation such as curriculum co-construction, faculty training, internships, and international exchanges. The construction and operation of Zhixin Platform have established an open, open-source system for collaboration in artificial intelligence technology innovation and education in China, providing strong support for the country's new generation of AI research achievements. Additionally, the successful operation of Zhixin Platform has introduced a new model for cultivating high-end technological talents in China. Through the platform's resource sharing and cooperation mechanisms, it not only accelerates the transformation of research outcomes but also offers students more opportunities for practice and innovation. This establishment of a science and education ecosystem helps create a virtuous cycle, promoting the continuous development and innovation of China's AI field.

### 3.1 Intelligent Updates to Teaching Content

Smart technologies allow teaching content to be updated in real-time according to the latest industry trends, ensuring that students learn knowledge and skills that are up-to-date. By incorporating artificial intelligence technology, teaching content can be dynamically adjusted based on students' real-time learning situations. For example, intelligent systems can analyze students' learning progress and understanding, automatically recommending suitable learning resources and exercises to enhance the personalization and effectiveness of teaching. Moreover, by introducing online resource libraries and open courses, students can independently choose their learning materials, meeting diverse learning needs.

#### *3.1.1 Incorporation of latest technology trends*

The introduction of intelligent auxiliary teaching systems enables teachers to more precisely analyze students' learning situations, achieving personalized teaching; while the application of virtual reality and augmented reality technologies allows students to explore knowledge in immersive environments, significantly enhancing their interest and efficiency in learning. Additionally, blockchain technology demonstrates unique value in educational assessments, ensuring fairness and transparency in evaluation processes. The integration of these cutting-edge technologies not only enriches educational resources but also promotes educational equity, allowing every student to access high-quality educational resources and laying a solid foundation for nurturing more talents with innovative abilities and practical skills for the future society.[2]

#### *3.1.2 Integration of interdisciplinary knowledge*

The integration of interdisciplinary knowledge has become key to driving innovation and solving complex problems. The intertwining of knowledge and skills from different fields provides us with broader perspectives and richer solutions. For instance, the combination of artificial intelligence and biotechnology is opening new chapters in the healthcare sector; principles of physics are applied in economics to help analyze market dynamics; and the fusion of art and technology has given rise to emerging industries like digital media. Such cross-disciplinary collaboration not only promotes the development of various disciplines but also brings unprecedented changes to society. Therefore, cultivating interdisciplinary thinking is crucial for both individuals and society.

#### *3.1.3 Focus on practical skill training*

In today's rapidly changing social environment, possessing solid practical skills means stronger competitiveness and adaptability. Therefore, educational institutions should emphasize and innovate practical teaching methods, such as laboratory operations, case analysis, simulation drills, etc., allowing students to learn in real or near-real situations. Additionally, encouraging students to participate in scientific research projects, internships, and community service activities broadens their horizons and increases experience. Moreover, establishing university-enterprise cooperation mechanisms is an effective way to enhance students' practical skills. Enterprises can provide internship positions for students, while schools can adjust course settings according to enterprise demands, jointly cultivating high-quality

talents that meet market needs.

#### *3.1.4 Continuous learning resource recommendations*

Leveraging big data analytics and machine learning algorithms, open educational resources (OER) can offer students continuous learning resource recommendations. These recommendations are based on students' learning history, interests, and goals, helping them to continue deep learning outside of class hours and maintain the coherence and depth of knowledge. Online learning platforms like Coursera and edX provide a wealth of course resources covering multiple academic fields. These platforms are interactive, allowing students to learn through videos, assignments, and quizzes, participate in project practices, obtain certification certificates, and enhance their professional competitiveness. It is recommended that students attend relevant offline lectures and online platforms like TED Talks to broaden their knowledge base and stimulate innovative thinking, thereby improving their overall quality.[3]

Construction of Resource Sharing Platform:

### 3.2 Intelligent Innovation in Teaching Methods

The application of smart technologies has promoted the diversification of teaching methods. For example, the flipped classroom model encourages students to autonomously learn theoretical knowledge through online platforms before class, focusing on discussions and practical operations during class time, enhancing classroom interaction and learning efficiency.

#### *3.2.1 Flipped classroom model*

The flipped classroom model is an innovative teaching method that reallocates the time distribution inside and outside the classroom, transferring the decision-making power of learning from teachers to students. By reversing the traditional teaching process, students autonomously learn new knowledge before class through videos, reading materials, etc., while classroom time is used for discussions, problem-solving, and deepening understanding. Under this model, students are no longer passive recipients of knowledge but active participants in learning, which not only improves their self-learning ability but also cultivates their critical thinking and problem-solving skills. For teachers, the flipped classroom signifies a role shift from knowledge transmitters to learning guides and facilitators. Teachers design courses according to teaching objectives, ensuring students master core knowledge points before class and deepen understanding through activities during class. Course content is modularized and specialized, constructing a complete and logical knowledge system to avoid fragmented presentation of knowledge. Teachers need to design high-quality teaching videos and other digital resources to support students' autonomous learning and conduct effective interactions and guidance in class. The flipped classroom model plays a significant role in improving teaching quality and student learning outcomes, encouraging proactive learning, making the teaching process more personalized and efficient.

#### *3.2.2 Project-Based learning (PBL)*

PBL is a student-centered teaching method that enhances students' practical abilities and problem-solving skills by involving them in the design and implementation of real projects. Teachers, based on curriculum standards and students' learning needs, identify core knowledge points for the project and design challenging tasks to stimulate students' interest in learning and encourage them to apply their knowledge through exploration and practice. Under teachers' guidance, students develop project plans, assign tasks, and solve problems through practical activities. After completing the project, students reflect on their learning experiences and evaluate the project outcomes. PBL emphasizes student-centered learning through real or simulated project tasks, allowing students to construct knowledge and experience in the process of completing projects. It encourages active participation in learning, promoting innovative thinking and problem-solving skills through practice, exploration, and collaboration.

PBL is contextual, meaning knowledge is not learned in isolation but within specific, real-life situations. The benefits of PBL include its emphasis on interdisciplinary knowledge integration, enabling students to apply knowledge from different subjects to solve real problems through comprehensive project designs. PBL also focuses on teamwork, enhancing understanding and application of knowledge through personalized and collaborative learning environments, which also improve problem-solving skills, foster innovative and critical thinking, and lay a solid foundation for future studies and careers.[4]

#### *3.2.3 Collaborative learning strategies*

Collaborative learning strategies emphasize teamwork and mutual assistance, promoting knowledge sharing among students, improving problem-solving abilities, and enhancing team spirit. To implement this strategy, teachers first design reasonable group allocation schemes to ensure every member can leverage their strengths. They then clarify task objectives and division of labor, ensuring each participant knows their responsibilities. Additionally, encouraging open discussions creates a safe and inclusive learning environment where everyone feels confident expressing their ideas without fear of criticism. Regular reflection meetings are organized to share what was learned during cooperation, challenges encountered, and how they were overcome. This deepens understanding of knowledge points and cultivates good communication skills and social responsibility.

#### *3.2.4 Gamification in education*

Gamification in education involves incorporating game elements into the teaching process to make learning more engaging and interactive. This approach typically includes point systems, level advancement, task challenges, and virtual rewards, making the learning process more lively and fun. Teachers design various game activities for students to master knowledge points while completing tasks. Examples include puzzle games and role-playing simulations. These activities not only spark curiosity but also develop teamwork and problem-solving skills. Gamification provides

instant feedback, helping students understand their progress and identify issues promptly. Through competition and collaboration, students learn from each other in a relaxed and enjoyable atmosphere. Gamification is becoming an increasingly popular teaching strategy in modern education for its unique appeal, enhancing learning efficiency and fostering innovative thinking and practical abilities.

### 3.3 Intelligent Improvement of the Teaching Evaluation System

Traditional teaching evaluations often rely on final exams or project works, which fail to comprehensively reflect students' learning processes and ability enhancement. The application of intelligent technology enables formative assessments, allowing teachers to collect detailed and objective evaluations through learning management systems.

#### *3.3.1 Formative assessment systems are crucial for educational innovation*

emphasizing process over mere outcomes. This dynamic and continuous evaluation method aims to promote holistic development by observing and providing real-time feedback on students' learning processes. It focuses not only on knowledge acquisition but also on skill enhancement, emotional attitudes, and values formation. Teachers act as guides and observers, using daily homework, group discussions, and classroom performance to gather information from multiple perspectives. Formative assessments stress immediacy and specificity, encouraging learning through trial and error, self-reflection, and peer review to adjust learning strategies continually. This approach helps develop self-monitoring skills and critical thinking, making students more proactive learners. It also provides valuable teaching feedback, helping teachers adjust plans and methods to meet individual needs.[5]

#### *3.3.2 Competency-Based assessment*

In the field of education today, competency-based assessment is gradually becoming the mainstream evaluation method. This assessment model emphasizes the cultivation of students' practical skills, innovative thinking, and problem-solving abilities rather than mere rote memorization of knowledge. It encourages students to apply theoretical knowledge in practice, showcasing their talents through projects and case analyses. Teachers shift from traditional knowledge transmitters to guides and evaluators, designing real-life tasks, observing and documenting student performance, and providing personalized feedback. In this model, evaluation criteria are more diversified, focusing not only on outcomes but also on learning attitudes, teamwork spirit, and self-improvement during the process. Competency-based assessment promotes educational equity, allowing every student to shine in their areas of strength and cultivating more talents with practical experience and innovation for society.

#### *3.3.3 Peer review mechanism*

The peer review mechanism is a widely used assessment method in education that enhances learning outcomes through mutual evaluation among students. Under this mechanism, students receive feedback not only from teachers but also from classmates, gaining different perspectives and suggestions. This approach helps develop critical thinking, communication skills, and teamwork spirit.

When implementing peer reviews, clear standards or guidelines are usually provided to ensure fairness and effectiveness. These standards may include accuracy of content, clarity of expression, and logical coherence. To maintain participants' enthusiasm, it is essential to emphasize positive encouragement and avoid overly harsh or negative comments.

Teachers play a guiding role throughout this process, training students beforehand on how to give constructive feedback and supervising the entire procedure to ensure smooth operation and address potential issues promptly. When used correctly, peer review can deepen students' understanding of their work, strengthen class cohesion, and foster a positive learning environment.

## 4 CASE STUDY: APPLICATION OF SMART TECHNOLOGY IN PRODUCT DESIGN TEACHING

### 4.1 Peking University School of Stomatology's Virtual Simulation Smart Lab, AI Technology Reshapes Experimentation and Practice

In today's rapidly advancing technology era, artificial intelligence (AI) is profoundly transforming our learning methods. The School of Stomatology at Peking University recently announced the official launch of its self-developed virtual simulation smart lab, marking a new experimental and practical approach for fields requiring high manual dexterity. This innovative initiative not only reshapes teaching modes but also realizes the independent development of the world's first mixed-type oral virtual simulation training system, providing valuable teaching resources for domestic universities.

The Peking University School of Stomatology's Virtual Simulation Smart Lab is a multi-dimensional intelligent integrated training platform that combines virtual simulation technology, big data support, intelligent IoT, intelligent management, and smart learning and evaluation. The lab consists of teaching areas, online training zones, and virtual simulation training zones, aiming to master skills based on theoretical foundations and provide timely feedback on skill levels through various training methods.

The highlight of the lab lies in its innovative teaching mode. By integrating online and offline, virtual and physical modes, the lab optimizes training methods and improves teaching quality. Students can engage in virtual simulation experiments and automated assessments in the online training area, while the virtual simulation training area offers diverse types of force-feedback virtual simulation training and evaluations. This variety of training methods enhances learning efficiency and practical skills.

Additionally, the lab innovates operational management models. Through an intelligent "appointment-management-evaluation" integrated system, the lab efficiently manages teaching resources and service processes. The system and resources are shared with domestic universities, having served society and students 18,000 times to date, demonstrating its social value and influence.

In this lab, students transition from passive knowledge recipients to active explorers and practitioners. They simulate real-world surgical procedures in a virtual environment, with each practice honing their skills. The introduction of virtual simulation technology allows students to try complex surgical procedures without risks, crucial for enhancing their hands-on abilities and clinical thinking.

The establishment of the Peking University School of Stomatology's Virtual Simulation Smart Lab also profoundly impacts teaching methods for educators. Teachers can utilize this platform for more flexible and diverse teaching activities, adjusting content and methods based on student feedback to better meet their needs.[6]

The success of the Peking University School of Stomatology's Virtual Simulation Smart Lab provides a new perspective for the education sector in China and globally. It demonstrates the immense potential of AI technology in education, with prospects for broader application across more professional fields. As technology continues to advance and innovate, we have reason to believe that education will become increasingly intelligent, personalized, and efficient.

### 4.2 Tsinghua University Leads the Innovation of AI Technology in Educational Models, with Multiple Schools Following to Explore New Paths for Intelligent Teaching

On March 5th, Tsinghua University announced that the application of AI technology in education is gradually changing traditional teaching models, bringing new opportunities and challenges to educational instruction. Starting from the fall semester of 2023, the university launched a pilot program titled "AI-Empowered Teaching," with eight courses participating in the pilot phase. Among these, five courses have completed the development and deployment of their intelligent teaching assistant systems. These AI teaching assistants provide round-the-clock personalized learning support, intelligent assessment, and feedback, as well as assist students in deep thinking and inspiring learning insights.

In the "Chemical Thermodynamics" course, Professor Lu Dian Nan from the Department of Chemical Engineering used over a hundred related articles and books for continuous training and calibration of a vertical model. The system has been preliminarily developed and now features capabilities for generating and answering questions. It was used as an auxiliary tool in the final project of the course at the end of the semester. Associate Professor Qian Jing from the School of Social Sciences, who teaches "Mind, Individual, and Culture," reported that after one semester of initial trials, students found the intelligent teaching assistant superior in terms of content accuracy, clarity of structure, degree of agreement, and helpfulness compared to general large models (such as GPT-4) and even human assistants.

Tsinghua University stated that in 2024, it plans to launch 100 pilot courses empowered by artificial intelligence. By leveraging AI to assist or deeply integrate into courses, the university aims to create AI teaching assistants and teachers, continuously innovate teaching scenarios, and enhance the efficiency and quality of teaching and learning.

Simultaneously, Peking University introduced its AI teaching assistant—Brainiac Buddy (BB), an AI interaction project based on GPT-4. In the fall semester of 2023, BB was implemented in the course "Mathematical Methods in Image Processing" taught by Professor Dong Bin, a distinguished professor at Peking University's Beijing International Center for Mathematical Research. Students were able to preview the course and establish personalized knowledge bases through interactions with "BB."

Nanjing University released the overall plan for its "General Education Core Curriculum System on Artificial Intelligence," set to be offered to all freshmen starting September 2024, a pioneering initiative among national universities. Led by top scholars including academicians, the course employs diverse teaching methods to help students understand AI applications across different fields. Tan Zhe Min, president of Nanjing University and an academician of the Chinese Academy of Sciences, stated that the university mobilized its entire strength to offer this core curriculum system. Tailored to the cognitive characteristics and disciplinary features of different majors, the course adopts a teaching format of "collective lectures + small group discussions + practical internships + AI teaching assistants," aiming to construct an AI classroom that deeply integrates AI technology and promotes in-depth human-machine interaction.[7]

Furthermore, the upgraded version of Ma Shang V2.0 was officially launched on the teaching cloud platform of Beijing University of Posts and Telecommunications. Developed, operated, and supported by the university's EZCoding team, Ma Shang is an intelligent programming teaching application platform empowered by large models. Addressing the urgent need for one-on-one tutoring in programming education, Ma Shang utilizes iFlytek's Spark Cognitive Model and BUPT's proprietary core technology to offer real-time, personalized, and heuristic programming guidance to students. For challenging problems that cannot be resolved independently, students can click the "Seek Help from Teacher" button, alerting teachers or teaching assistants via in-platform notifications and email, enabling timely and targeted guidance. This facilitates a collaborative service model between AI and teachers. Teachers can customize tutoring functions and modes for their classes, such as toggling code generation capabilities, and access detailed learning behavior data of allowing them to conduct teaching experiments freely and provide more targeted, high-quality educational services to students.[8]

### 4.3 The Integration and Challenges of Virtual Reality Technology in Product Design Education

With the rapid development of technology, virtual reality (VR) has gradually permeated various fields of product design education. Recently, numerous design institutes have adjusted their curriculum to incorporate VR technology, aiming to cultivate students' innovative design capabilities and practical skills in the context of the new era.

In basic design courses, aesthetics, as a traditional strength, provides students with a solid foundation in aesthetic appreciation. However, facing the comprehensive requirements of VR technology, institutions are actively exploring how to integrate aesthetic theories with virtual technologies to foster interdisciplinary thinking and innovative abilities. The foundation course in computer-aided design has also been strengthened, with three-dimensional modeling and image processing becoming essential skills for students to better construct and modify virtual environments. Through desktop virtual systems, teachers can transform theoretical knowledge into hands-on practice, allowing students to explore and experience the history and craftsmanship of product design in a virtual environment. In the teaching of historical and theoretical knowledge, virtual technology makes the content more vivid and engaging. Teachers can use desktop virtual systems to recreate specific historical periods' design environments, making students feel as though they are traversing time and witnessing the birth process of various design products firsthand. This all-encompassing display not only breaks through spatial and temporal boundaries but also deepens students' memory and understanding of product characteristics.

In professional courses, virtual reality software has become a focal point and challenge in teaching. Since much of this course content is presented in English, it presents significant barriers for art students who generally have weaker English proficiency. Moreover, these courses often involve multiple programming languages such as C and Java, demanding higher levels of coding ability and logical thinking from students. Surveys indicate that most art students find these technically intensive courses daunting and struggle to master them efficiently. For teaching materials and processing techniques, virtual technology also demonstrates substantial advantages. Traditionally, students could only understand the production process through pictures or on-site visits, which hardly spark interest. With virtual technology, however, teachers can present the manufacturing process in three dimensions, allowing students to experience more authentic and detailed process information in a virtual setting. This not only enhances students' cognitive level but also reduces the investment in time and economic costs. Besides classroom teaching innovation, virtual technology plays an important role in teacher-student communication and creative inspiration. By establishing convenient interactive platforms, teachers and students can exchange opinions on design works in real-time. Additionally, students can gain more inspiration based on the platform or collaborate on projects around a particular design theme, thereby eliminating communication barriers among students and significantly improving teaching efficiency.

In terms of modeling skill training, virtual modeling technology offers students more flexible and efficient learning tools. Students can freely modify models during the design process, using mouse movements to adjust and perfect product models. This iterative process helps students better master three-dimensional software application skills until they achieve satisfactory results. Finally, in comprehensive courses like product design, virtual experiments provide valuable practical experience for students. Through desktop virtual systems, students can conduct virtual experiments after completing three-dimensional modeling, such as car design or water dispenser design for home use. They can test whether the designed products meet safety standards and practical application needs in a virtual environment, thereby summarizing human application habits and specific demands to reference in designing products that align with usage habits.[9]

Institutions adopt mainly two modes in curriculum settings: one is integrating with related fields like digital technology to form a more complete teaching system; the other is offering elective courses, allowing students to choose learning content based on interests. While the former covers a wide range of knowledge, it may impose a heavy course load affecting overall student development; the latter might result in insufficient breadth of knowledge, making it difficult to elevate competency levels.

Educators face challenges in balancing course difficulty with student receptivity and integrating resources to improve teaching quality. They need to scientifically plan course content and teaching objectives by combining institutional characteristics, professional features, and actual student situations to ensure that while mastering necessary skills, students also develop innovative thinking and problem-solving abilities.

The application of virtual reality technology in product design education not only challenges traditional teaching models but also represents a comprehensive enhancement of future designers' capabilities. By continuously optimizing curriculum setup and teaching methods, we have reason to believe that future designers will be better equipped to meet the demands of the digital age, creating even more astonishing works.[10]

## 5 SUMMARY AND OUTLOOK

Although intelligent technologies have brought numerous opportunities to product design education, they still face several challenges in practical applications, such as high technological costs, insufficient teacher skills, and significant differences in student adaptability. These issues need to be addressed through policy support, teacher training, and technological optimization. In educational reform, it is crucial to strengthen interdisciplinary cooperation, promote the integration of intelligent technologies with educational theories, intensify technical training for teachers, enhance their ability to use intelligent technologies, and focus on educating students about information literacy to better adapt them to an intelligent learning environment.

It is anticipated that intelligent technologies will be more deeply integrated into product design education in the future, creating more personalized and efficient teaching models. Additionally, as technology continues to advance and costs

decrease, more educational institutions will be able to afford and widely adopt these technologies.

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**COMPETING INTERESTS**

The authors have no relevant financial or non-financial interests to disclose.

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# THEORETICAL BASIS AND INDEX SYSTEM OF CULTIVATED LAND CONSOLIDATION POTENTIAL EVALUATION

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**Abstract:** As a basic work in the field of land consolidation, land consolidation potential evaluation plays a vital role. It is not only a key component of the feasibility analysis of land consolidation projects, but also an indispensable basis for formulating land consolidation planning. In addition, land consolidation potential evaluation also provides a solid foundation for land consolidation zoning, project selection and arrangement of consolidation sequence. In this paper, we first reviewed and sorted out the research progress of the evaluation index system of cultivated land consolidation potential. Based on this, we further discussed the theoretical basis of cultivated land consolidation and various factors affecting the potential of cultivated land consolidation. The paper emphasizes that under the guidance of the concept of sustainable development, farmland consolidation is not only a simple land consolidation activity, but also a complex process involving the sustainable use of land. Therefore, the connotation of cultivated land consolidation potential should include improving the natural suitability, ecological rationality, economic effectiveness, technical feasibility and social acceptability of land. In view of this, the construction of cultivated land consolidation potential evaluation index system should comprehensively consider these aspects to ensure the comprehensiveness and accuracy of the evaluation.
**Keywords:** Arable land consolidation; Potential evaluation; Theoretical basis; Index system

## 1 INTRODUCTION

The concept of land consolidation first appeared in the law of the kingdom of Bavaria in 1886. Several European countries such as Germany, France and Russia carried out land consolidation practice earlier, and then Canada, Japan, South Korea, Yugoslavia, Hungary and other countries also carried out land consolidation [1-2]. The history of land consolidation in China can be traced back to the well field system in the ancient slave society [3], but the real sense of land consolidation in China was formally proposed and operated in the late 1990s. Marked by the establishment of the land consolidation center of the state land administration in 1998 and the launch of the first batch of land consolidation projects in 2001, the Chinese government will invest billions of yuan each year in the implementation of land consolidation projects, and the practice of land consolidation is being widely carried out throughout the country [2].

Land consolidation is the product of a certain regional social and economic development to a certain extent, which puts forward new requirements for land use. It is a new way for human to use land. Under the background of rapid socio-economic development and rapid population expansion, China's ability to ensure the development of land has encountered a bottleneck, with limited urban construction land and shrinking food supply. At the same time, land waste, land desertification and land pollution caused by extensive and irrational land use have further exacerbated the scarcity of land resources. As China's reserve land resources are limited by many factors, such as small quantity, poor quality, difficult reclamation and fragile ecological environment [4], the number of new land to be further developed is limited, which needs to tap the potential of the original land. As an effective way to effectively allocate land resources, promote efficient and rational land use and improve land supply capacity, land consolidation has played an important role in promoting the sustainable use and sustainable use of land resources, which came into being. Land consolidation refers to the process of comprehensively renovating, adjusting and reconstructing the land use status in a certain area according to the objectives and uses determined by the land use planning or urban planning by means of administration, economy, law and engineering technology, so as to improve the land utilization rate, production, living conditions and ecological environment [5]. Under the national conditions of China with more people and less land, while accelerating the process of industrialization and urbanization, it is undoubtedly a wise move to vigorously promote land consolidation by using China's land to feed the Chinese population and taking into account the triple goals of food, construction and environmental protection [6]. Article 41 of the land administration law of the people's Republic of China points out that the State encourages land consolidation, and the 2012 government work report of the State Council also focuses on strengthening land development, consolidation and reclamation. In 2012, the national land consolidation plan (2011-2015), prepared by the Ministry of land and resources in conjunction with relevant departments, was officially promulgated and implemented with the approval of the State Council. China's land consolidation practice is in full swing and in the ascendant.

In order to comply with the development trend of land consolidation and provide theoretical support for the practice of land consolidation, scholars at home and abroad have conducted many fruitful studies on land consolidation. Foreign research hotspots on land consolidation mainly focus on the causes of land consolidation [7-8], the evaluation of land consolidation project plan [9], the land allocation method in the process of land consolidation [10] and the evaluation of

land consolidation effect [11-12], while the research on land consolidation potential is less involved. Land consolidation potential evaluation is a basic work of land consolidation. It is an important part of the feasibility analysis of land consolidation projects and the fundamental basis for formulating land consolidation planning. It is also the basis for land consolidation zoning, land consolidation project selection and consolidation sequence arrangement. It is of great significance to carry out land consolidation potential evaluation research for reasonable and effective arrangement of land consolidation work. Many Chinese scholars have done a lot of research on the connotation [13], investigation [14-15], evaluation methods [16] and quantitative evaluation [17-19] of land consolidation potential, but systematic research on the evaluation index system of land consolidation potential is rare. At present, China's land consolidation is mainly concentrated in farmland consolidation and rural residential land consolidation. This paper mainly discusses the index system of farmland consolidation potential evaluation.

Cultivated land consolidation potential refers to the improvement of cultivated land comprehensive production capacity through the implementation of consolidation measures in a certain area under certain economic and technological conditions [19]. China is a vast country with different natural conditions and economic, social and technological conditions. The ways, directions and characteristics of land use vary greatly. The problems faced by land use and consolidation are also different. The standards of land consolidation in different regions are also different. The potential of land consolidation shows obvious regional differences. Because the factors affecting the potential of land consolidation are regional, diverse and complex, the index system for evaluating the potential of farmland consolidation is also diverse. Quchenxiao et al. Calculated the potential of cultivated land consolidation in Henan Province Based on the coefficient of cultivated land consolidation [20]. Wangqian and others selected four indicators of per capita new grain output, per capita new cultivated land, new grain output and new cultivated land coefficient to evaluate the potential of cultivated land consolidation in Lanzhou [21]. Gongjian and others built an index system to study the land consolidation potential of Baokang County in Hubei Province from three aspects: the gap between the theoretical per unit yield and the actual per unit yield of cultivated land, the increased effective area of cultivated land after consolidation, and the improvement degree of cultivated land production capacity after consolidation [22]. Fanjinmei and others believe that the two factors affecting farmland consolidation are the net increase in the number of farmland and the improvement in the quality of farmland [19]. However, wulianglin and others believe that besides the potential of "quantity" and "quality", under the background of building a modern agricultural system in China, we should pay more attention to the ability of farmland consolidation to improve the level of land scale. Based on this, we quantitatively evaluated the potential of farmland scale consolidation by using landscape pattern indicators such as topographic indicators, land resource abundance index, land patch area index, land patch shape index and land aggregation index [23]. Zhuyubi and others believe that building the evaluation index system of cultivated land consolidation potential needs to start from two aspects: endogenous and exogenous variables that affect the potential of cultivated land consolidation. Endogenous variables include the level of cultivated land use, the ability to improve the level of cultivated land productivity and the degree of improvement of cultivated land ecological environment. These are the theoretical potential of cultivated land consolidation. Exogenous variables include economic benefits, social needs, infrastructure supporting conditions and enthusiasm for cultivated land consolidation. These are the limiting factors that determine whether theoretical potential can be transformed into real potential [24].

In general, China has carried out a lot of research work on the potential of cultivated land consolidation, and has also carried out some work on its potential evaluation index system. The evaluation index system has gradually changed from a single index evaluation method to a multi index comprehensive evaluation method, and the evaluation index design has also changed from mainly increasing the number of cultivated land to paying equal attention to increasing the number of cultivated land, improving the quality of cultivated land and improving the ecological environment. Cultivated land consolidation is an extremely complex system engineering, so the index system for evaluating its potential should avoid being single and one-sided. At the same time, the evaluation of cultivated land consolidation potential in China is still in the exploratory stage. We should make it substantive and in-depth through the study of comprehensive and systematic evaluation index system and evaluation standards, so as to better serve the practice of land consolidation.

## 2 THEORETICAL BASIS OF CULTIVATED LAND CONSOLIDATION POTENTIAL

According to the actual work of farmland consolidation in China at present, the potential of farmland consolidation refers to taking a series of measures in terms of administration, economy, law and technology to consolidate the farmland and roads, ditches, forest networks, ridges, graves, sporadic construction land and unused land in a certain area in a certain period of time according to the overall land use planning, so as to improve the comprehensive production capacity of farmland. This comprehensive production capacity is reflected in the increase of arable land use rate and output rate, the increase of arable land available area, the improvement of ecological environment, the decline of production costs, the improvement of infrastructure and the optimization of property relations. According to the regulations for the preparation of land development and consolidation planning, China's arable land consolidation potential includes the reclamation of flat graves, filling ditches, scattered homesteads and all kinds of abandoned and idle land, the development of scattered unused land, the improvement of field roads, forest network supporting facilities, ditch reconstruction (changing underground canals, sprinkler irrigation, etc.) and the transformation of medium and low yield fields, so as to build modern high standard farmland and improve land utilization and output [25]. However, this is only the natural potential of cultivated land consolidation. Whether it can be turned into real potential and the size of it

are affected by capital, technology, location, social support and other factors. With the increasing population growth, land degradation and environmental problems, the sustainable use of land is the basic guarantee for China to achieve sustainable development strategy [26-27]. Land consolidation is an activity taken to eliminate the unfavorable factors in the original land use system in order to better meet human requirements for land in the process of land use. Land use system is a huge system composed of subsystems such as natural subsystem, ecological subsystem, social subsystem, economic subsystem and technical subsystem, which interact, interweave and penetrate each other. The irrationality of any subsystem will affect the whole body and affect the overall function of land. Under the concept of sustainable development, land consolidation is not a temporary expedient, but an important project to achieve the strategic goal of sustainable development of land resources [28]. Therefore, the potential of cultivated land consolidation is the degree of implementing cultivated land consolidation activities to achieve natural suitability, ecological rationality, economic effectiveness, technical feasibility and social acceptability. The connotation of cultivated land consolidation potential can be understood from the following aspects.

### 2.1 Natural Suitability

Land consolidation is a systematic arrangement of the current situation of land use, and its process involves a detailed investigation of the types, quantity, structure, quality, distribution and existing problems of various land resources to be renovated. Through this process, the aim is to eliminate the limiting factors in the process of land use, so as to enhance the production potential of land. In view of the differences of land restrictions in different regions, as well as the inherent characteristics of fixed location, quality differences, diminishing returns and the relative difficulty of changing the direction of land use, the land consolidation work must design the most appropriate land use mode according to the actual situation of each region. For example, in the hilly area with large slope, in order to prevent soil erosion, it should be reduced to transform it into terraced fields, and returning farmland to forest is the most appropriate land use strategy in this area. The core of land consolidation is to eliminate unreasonable land use patterns, reduce the limiting factors of land use, and make rational allocation according to the inherent characteristics of land resources.

### 2.2 Ecological Rationality

Ecological rationality refers to that the land use system can achieve a good operation state in terms of ecology, ensure that land use will not destroy the normal ecological process, and make the key ecological processes such as water cycle, nutrient cycle, energy flow and biological migration fully and reasonably carried out. From the course of human development, we can clearly see that any land use practice must pay enough attention to ecological factors, which is the key to ensure the sustainable use and protection of land resources. Therefore, land consolidation activities should not only eliminate the negative factors that may affect the ecological function of land, but also actively explore and implement various methods to improve the overall ecological operation function of land, so as to achieve ecological rationality.

### 2.3 Economic Effectiveness

Economic benefits constitute the core driving force of land consolidation activities, and the benefit of its input and output is the primary goal of farmland consolidation. Only when the economic benefits of farmland consolidation exceed its cost input can the farmland consolidation project be sustainable. At the same time, if farmland consolidation can produce more significant economic benefits, it can stimulate the enthusiasm of the society for farmland consolidation activities, and then attract more capital investment to ensure the sustainable development of farmland consolidation activities.

### 2.4 Technical Feasibility

With the continuous progress and rapid development of science and technology, those cultivated land resources that were once considered to be unable to be effectively utilized have now been fully developed and utilized. This not only reduces the various restrictive factors faced in the use of cultivated land, but also significantly improves the resistance of cultivated land to drought and flood disasters, and ensures the stability and reliability of food production. The feasibility of technology is not only reflected in the cultivated land itself, but also includes the improvement and upgrading of related roads, ditches and infrastructure. In addition, the land leveling work, the rational consolidation of fields and the optimization and adjustment of land use structure are important components of technical feasibility. They work together to make the use of land resources more efficient and scientific.

### 2.5 Social Acceptability

With the continuous growth of population, the pressure on land resources is increasing, which leads to the continuous reduction of per capita cultivated land area. At the same time, the decline of grain self-sufficiency has also become a problem that can not be ignored. These factors work together, making farmland consolidation particularly urgent and necessary. Farmland consolidation is not only a technical activity, but also involves many people and interest groups, whose interests and demands are often complex. If the plan and action of land consolidation cannot be widely accepted

and supported by the society, it will be difficult to carry out this work smoothly. Therefore, improving production capacity, improving living conditions, optimizing landscape layout and realizing the rational distribution of land resources are the key factors that affect the acceptance of the masses and interest groups on farmland consolidation. Only by achieving balance and progress in these aspects can we ensure that the farmland consolidation work is recognized by the society and implemented smoothly.

## 3 ANALYSIS OF INFLUENCING FACTORS OF CULTIVATED LAND CONSOLIDATION POTENTIAL

### 3.1 Analysis of Influencing Factors for Improving Natural Suitability

When making use of cultivated land, we must fully consider the natural endowment of the region and adopt the strategy of adjusting measures to local conditions according to the actual local conditions. The thickness of cultivated land, the content of organic matter and the depth of groundwater will have a direct impact on the growth and production of different crops. For example, the land with thick tillage layer and rich organic matter content is more suitable for planting crops that need deep soil and rich nutrients, while the place with shallow groundwater depth may be more suitable for planting crops that are resistant to water and moisture. In addition, slope and elevation are also the limiting factors that can not be ignored in the use of cultivated land. The land with large slope is prone to water and soil loss, while the area with high elevation may be restricted by climate conditions. Therefore, in order to pursue advantages and avoid disadvantages, we need to reasonably adjust the land use structure and field scale structure to ensure the efficient and sustainable use of land resources.

### 3.2 Analysis of Factors Affecting Ecological Rationality

The factors that affect ecological rationality are actually those that can affect key ecological processes such as water cycle, nutrient cycle and energy flow. These factors include but are not limited to water and soil conservation rate, vegetation coverage, biodiversity, farmland shelterbelt area, farmland shelterbelt access index, basic farmland protection rate, landscape optimization degree and various facilities for disaster prevention and control. Specifically, the level of soil and water conservation rate is directly related to the degree of soil erosion and the loss of surface water, while the vegetation coverage reflects the lushness of surface plants and the health of the ecosystem. Biodiversity is a key indicator of ecosystem stability and stress resistance, which involves species richness and niche diversity. The area and accessibility index of farmland shelterbelts reflect the spatial distribution of shelterbelts and their ability to protect farmland. The protection rate of basic farmland is directly related to food security and agricultural sustainable development. Landscape optimization degree is related to the beauty of ecological landscape and the coordination of ecological functions. Finally, various facilities used to prevent and control disasters, such as flood embankment and drainage system, are important means to ensure ecological security and reduce the loss of natural disasters.

### 3.3 Analysis of Factors Affecting Economic Effectiveness

When discussing the connotation of cultivated land consolidation, it is not difficult to find that the economic effectiveness of cultivated land consolidation is mainly reflected in two aspects: the first is the significant increase in the effective use area of cultivated land, and the second is the significant increase in the yield per unit of cultivated land [19]. Specifically, the factors affecting the increase of the effective use area of cultivated land include the reduction of the proportion of ditches, roads and ridges. The optimization of these factors can effectively improve the utilization rate of cultivated land, so as to increase the effective use area of cultivated land. In addition, the increase in the number of new cultivated land is also an important factor to promote the increase in the effective use area of cultivated land. As for the factors affecting the increase of per unit cultivated land output, they include the concentration of fields, the degree of contiguity of fields, the degree of flatness of fields and the average scale of fields. By improving the quality of these aspects, it can effectively promote the increase of unit cultivated land output, and then enhance the economic effectiveness of cultivated land consolidation.

### 3.4 Analysis of Influencing Factors for Improving Technical Feasibility

An important goal of farmland consolidation is to create high-quality farmland that can resist drought and flood disasters. Therefore, the technical factors affecting farmland consolidation include many aspects. First of all, the size of irrigated farmland area is directly related to the production capacity and drought resistance of farmland. A larger irrigation area helps to improve the overall agricultural output. Secondly, the degree of flood control and drainage is a key technical index to ensure that farmland is not affected by floods in the rainy season, which involves the construction and maintenance of drainage system. In addition, the accessibility of field roads is very important for the entry and exit of agricultural machinery and the transportation of agricultural products. A good road network can significantly improve the efficiency of agricultural production. Motor well density is an important index to measure the convenience of farmland irrigation, which affects the irrigation frequency and efficiency of farmland. The connectivity of drainage channels and water conservancy facilities are also factors that can not be ignored. They ensure that the farmland can timely and effectively remove ponding in the rainy season and prevent crop damage caused by excessive ponding.

### 3.5 Analysis of Influencing Factors of Increasing Social Acceptability

As an important means of land management, land consolidation is gradually rising with the sustainable development and progress of social economy. Generally, when the economic development level of a region reaches a certain height, people's demand for rational allocation and efficient use of land resources will become more urgent. Therefore, as an important way to improve land use efficiency and output, the acceptance of cultivated land consolidation is often in direct proportion to the level of local economic development. With the further development of economy, the urgency and participation of the masses in farmland consolidation will also increase accordingly. In addition, the adequacy of land consolidation funds and government policy support and guidance are important factors affecting the social acceptability of land consolidation. Only when these conditions are met can the land consolidation work proceed smoothly and achieve the expected results.

## 4 ESTABLISHMENT OF EVALUATION INDEX SYSTEM OF CULTIVATED LAND CONSOLIDATION POTENTIAL

Land consolidation potential assessment is an activity to comprehensively evaluate the improvement of natural suitability, ecological rationality, economic effectiveness, technical feasibility and social acceptability based on the detailed investigation of the types, quantity, structure, quality, distribution and existing problems of various land resources to be consolidated and combined with the future land use mode. In view of China's vast geographical scope and the different natural conditions, economic, social and technological conditions in different regions, there are significant differences in the mode, direction and characteristics of land use, which makes the problems faced by land consolidation vary, and the land consolidation standards are also different, resulting in significant regional differences in land consolidation potential. Therefore, the construction of rural land consolidation potential evaluation index system should take the regional situation - land use status - land use objectives - factors affecting rural land consolidation potential - rural land consolidation potential evaluation index - evaluation criteria as the logical main line. When setting the evaluation index, we must follow the regional principle, comprehensive principle, scientific principle, operability principle and sustainability principle, and build the evaluation index system of rural land consolidation potential from the five dimensions of natural suitability, ecological rationality, economic effectiveness, technical feasibility and social acceptability according to the connotation of cultivated land consolidation potential.

### 4.1 Selection of Natural Suitability Index

The index reflects the adaptability of farmland consolidation activities to local conditions, and it is the natural potential of land consolidation in specific regions and natural conditions. Relevant indicators include field size, thickness of cultivated layer, organic matter content, groundwater depth, slope index and elevation index.

### 4.2 Selection of Ecological Rationality Index

The index reflects whether the farmland consolidation activities follow the ecological principle, which is the ecological potential of land consolidation without destroying the local natural environment and maintaining regional ecological security. Relevant indicators include soil and water conservation rate, vegetation coverage, biodiversity index, farmland shelterbelt area index, farmland shelterbelt access index, basic farmland protection rate, pollution prevention and control rate, natural disaster prevention and control rate, and landscape optimization degree.

### 4.3 Selection of Economic Effectiveness Index

The indicators reflect that farmland consolidation activities reduce production costs and increase land output, so as to achieve good economic benefits, which is the economic potential of land consolidation. Relevant indicators include new cultivated land coefficient, new grain coefficient, field concentration index, field contiguity index, field leveling index, average field size index, and input-output rate.

### 4.4 Selection of Technical Feasibility Index

The indicators reflect the potential achieved by the implementation of farmland consolidation with existing technologies. Relevant indicators include effective irrigation area index of cultivated land, flood control and drainage degree, field road accessibility, well density index, drainage channel connectivity index, and water conservancy facility connectivity index.

### 4.5 Selection of Social Acceptability Index

Indicators show the degree of external support for the smooth implementation of farmland consolidation activities. Relevant indicators include local economic development, population, average grain yield per unit area, investment in land consolidation, local government support, and farmers' participation.

In view of the availability of the above indicators and the differences in natural conditions, socio-economic conditions and ecological environment among different cultivated land consolidation areas, this study fully considered a variety of

factors affecting the potential of cultivated land consolidation. Among the many potential influencing factors, the key factors that can reflect the potential of local cultivated land consolidation were selected, and then the evaluation index system of cultivated land consolidation potential adapted to the local actual situation was constructed. Then, the evaluation indexes were quantified (the core is the determination of threshold), and finally the weight of each index was determined to calculate the potential value of cultivated land consolidation.

## 5 CONCLUSION

Many factors have an impact on the potential of rural land consolidation. When evaluating its potential, we should not only pay attention to its theoretical potential, but also fully consider the constraints that restrict its transformation into real potential. The construction of rural land consolidation potential evaluation index system should take the regional situation, land use status, land use objectives, factors affecting rural land consolidation potential, rural land consolidation potential evaluation indexes and evaluation standards as clues, and under the guidance of the concept of sustainable development, comprehensively consider the multiple functions of the land use system, so as to clarify the connotation of cultivated land consolidation potential, which should cover the potential of natural suitability, ecological rationality, economic effectiveness, technical feasibility and social acceptability. Based on this, this paper constructs the evaluation index system of cultivated land consolidation potential from the five dimensions of natural suitability, ecological rationality, economic effectiveness, technical feasibility and social acceptability.When constructing the evaluation index system, it is necessary to quantify each index to ensure the objectivity and operability of the evaluation process.

Secondly, the construction of the evaluation index system should follow the principles of scientificity, systematicness, comparability and dynamics. Scientificity requires that the selection of indicators must be based on the in-depth study of theory and practice; Systematicness emphasizes that the indicators should be interrelated to form an organic whole; Comparability requires comparability of indicators in different regions and time points; Dynamic means that the index system should be able to adapt to land use change and policy adjustment, with a certain degree of flexibility.

In practical application, the construction and application of the evaluation index system need to be combined with the actual situation of the specific region. For example, for areas with rich land resources but low degree of development, we should focus on the natural suitability and ecological rationality of land; For areas with tight land resources and dense population, more attention should be paid to the economic effectiveness and social acceptability of land. In addition, as the key factor to realize the potential of land consolidation, the evaluation standard of technical feasibility should also be adjusted according to the technical development level and actual operation ability of the region.

To sum up, the construction of rural land consolidation potential evaluation index system is a systematic project, which needs to comprehensively consider various factors and carry out personalized design in combination with regional characteristics. The scientific and reasonable evaluation index system can provide strong support for land consolidation planning and decision-making, and promote the sustainable use of land resources.

## COMPETING INTERESTS

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# FACTORS INFLUENCING THE ADOPTION OF GENERATIVE AI TECHNOLOGY BY CHINESE MAINSTREAM MEDIA JOURNALISTS: A FIELD STUDY BASED ON J PROVINCE BROADCASTING AND TELEVISION

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**Abstract:** Generative AI technology is becoming increasingly important for media content production in the era of intelligent media. However, its adoption among some Chinese mainstream media has been slow. While previous research has largely focused on the macro-level impacts of generative AI on the journalism industry, the individual adoption behaviors of journalists have been underexplored. This study applies the Unified Theory of Acceptance and Use of Technology (UTAUT) model and the Technology-Organization-Environment (TOE) framework, using participatory observation and in-depth interviews at J Province Broadcasting and Television Station to identify the factors influencing AI adoption among Chinese journalists. The research was conducted in three phases, each employing different sampling and interview methods, and involved 30 journalists from diverse regions and media types. The findings reveal that social influence and curiosity drive initial adoption, while performance expectancy and effort expectancy are critical for continued use. Key barriers include organizational pressures, unfair compensation, technological limitations, copyright issues, and information security concerns. By integrating the UTAUT model with the TOE framework, this study offers a comprehensive analysis, identifying new influencing factors and providing actionable recommendations, such as optimizing compensation structures, clarifying technology application scopes, and enhancing awareness of human-machine collaboration. This research extends the application of these theoretical frameworks to a new context and provides empirical evidence supporting the ongoing transformation of media technology, offering practical insights for media organizations navigating the challenges and opportunities of generative AI technology.
**Keywords:** Generative AI; Mainstream media journalists; Technology adoption; Influencing factors,; Participatory observation

## 1 INTRODUCTION

Generative AI technology, with its outstanding multi-modal content generation capabilities and strong cross-cultural adaptability, has redefined the boundaries of human-machine interaction, enhancing both the emotional resonance and media value of content[1]. This technology has significantly bolstered media productivity, influence, and service quality[2]. Adopting and effectively utilizing AI technology is not only crucial for the professional development of journalists in the era of intelligent communication but also essential for driving innovation within the news industry and facilitating the transformation of media organizations.

However, some mainstream media outlets in China are exhibiting a delayed adoption of generative AI technology, with certain journalists showing clear resistance to embracing new technologies. Compared to management, journalists display a more pronounced psychological resistance[3]. Consequently, this paper uses J Province Broadcasting Station as a case study to conduct an in-depth analysis of the key factors influencing journalists' willingness to adopt generative AI technology through participatory observation and in-depth interviews. The aim is to provide theoretical insights and practical guidance for advancing human-machine collaboration and promoting the intelligent transformation of the news industry.

## 2 THE RELATIONSHIP BETWEEN GENERATIVE AI AND JOURNALISTS

The impact of generative AI technology on the news industry ecosystem extends beyond merely transforming content paradigms; it transcends functional aspects to reshape human-machine interaction patterns and alter the professional identities and perceptions of journalists[4]. The academic debate continues over whether generative AI is a boon or a bane.

Technological optimists argue that generative AI is a pivotal driver for the transformation and upgrading of the news industry . Its innovative applications in audiovisual news creation, smart application development, and cross-language communication [5] effectively reduce the repetitive labor burden on journalists. Furthermore, generative AI's auxiliary roles in public opinion monitoring, emotional intelligence, information filtering, and risk assessment significantly contribute to managing public discourse and establishing a healthy and orderly online information environment [6].

Conversely, scholars skeptical of this technology argue that the widespread application of AI in content generation (AIGC) has steered news production towards data-driven and machine-led processes, undermining the humanistic

values of journalism and challenging the professional judgment and creativity of journalists . The proliferation of formulaic, homogenized, robot-produced news blurs the diversity and richness of news expression[7], muddies the professional boundaries of journalistic behavior[8], transforms journalists from storytellers into data managers and analysts , and shifts the human-machine relationship towards competition[9].

Previous research has primarily focused on the functional contributions and value impacts of generative AI on the news industry but has paid insufficient attention to the dynamic and complex process of technology diffusion, particularly neglecting the subjective willingness of journalists. In the context of the accelerated arrival of the technological axis era, while human-machine symbiosis is the general trend, balancing technological progress with humanistic care—ensuring that technology serves the sustainable development of journalism rather than becoming mere technological accumulation—remains an urgent issue.

## 3 THEORETICAL BASIS OF TECHNOLOGY ADOPTION: UTAUT MODEL AND TOE FRAMEWORK

At the intersection of information systems and user behavior research, the domain of technology adoption offers rich perspectives and tools for exploring the drivers and barriers affecting journalists' adoption of generative AI technology, particularly through the Unified Theory of Acceptance and Use of Technology (UTAUT) model and the Technology-Organization-Environment (TOE) framework. These frameworks provide complementary insights at both the micro-individual and meso-organizational levels, establishing a solid theoretical foundation for such studies.

The UTAUT model, a comprehensive theoretical framework in the technology adoption field [10], outlines four core determinants of individual technology adoption: 1) Performance Expectancy—the belief that using the technology will enhance job performance; 2) Effort Expectancy—the ease associated with the use of technology; 3) Social Influence—the impact of significant others on an individual's decision to adopt the technology; and 4) Facilitating Conditions—the degree of organizational and technological infrastructure support. Additionally, age, gender, experience, and voluntariness act as moderating variables, further enriching the theory. The UTAUT model has demonstrated high explanatory power in understanding technology adoption behaviors and has been widely applied across various fields, including psychology, education , and communication studies. How these elements interact within the mainstream media context to influence journalists'adoption behaviors constitutes a critical dimension of the analysis.

The TOE framework offers a another unique tri-dimensional perspective[11]encompassing technology, organization, and environment, providing a comprehensive analytical framework for understanding technology adoption at the organizational level. It delves into how internal organizational structures and cultures, along with external environmental changes, profoundly impact technology adoption. This framework aids in identifying and understanding complex factors beyond the individual level—such as organizational culture, resource allocation, policy orientation, and market competition—that collectively influence decision-making and implementation processes in technology adoption.

Current technology adoption studies often rely on quantitative methods [12], particularly utilizing surveys and structural equation modeling for analysis [13], with qualitative research being relatively scarce[14]. However, qualitative research holds unique advantages in exploring the subjective perceptions, cognitive changes, and behavioral logics of journalists during the adoption process of generative AI technologies. Methods such as participatory observation and in-depth interviews allow for deep immersion into the journalists' work and life contexts, capturing subtle details and underlying motivations that are difficult to reach through quantitative approaches. This provides a richer and more vivid empirical basis for theory building and offers more targeted guidance and recommendations for practice.

In summary, this paper combines the UTAUT model with the TOE framework to construct an analytical framework that addresses both the psychological and behavioral characteristics of individual journalists and the complex environments of mainstream media organizations. Additionally, key variables from other related studies, such as cost-benefit, technological superiority, organizational size[15], technological ethics, efficiency enhancement[16], peer pressure, perceived popularity, individual innovativeness, and technology anxiety, can also provide effective insights into the following research questions:

RQ1: What is the current state of generative AI technology adoption among mainstream media journalists?

RQ2: What are the factors driving the initial and continued adoption of generative AI technology by mainstream media journalists?

RQ3: What are the barriers to the adoption of generative AI technology by mainstream media journalists?

## 4 METHODS AND DATA COLLECTION

This study employs participatory observation and in-depth interviews, conducted from September 2023 to January 2024 at the J Province Broadcasting and Television Station, to observe the work practices and technology usage of journalists. Compared to quantitative methods, this approach is more adept at capturing subtle differences and underlying motivations.

The choice of J Province Broadcasting and Television Station as the field site is primarily based on a comprehensive assessment of its industry background and technological capabilities. First, as an audiovisual media entity, it offers a more diverse array of reporting formats, richer technological application scenarios, and higher integration of technology compared to traditional print media. Second, J Province Broadcasting and Television Station ranks among the top in the

province and nationwide in terms of news convergence broadcasting index, news brand influence, economic strength, overall influence, and technology reserves, making it highly representative and valuable for research.

To ensure the systematic and scientific gathering of data, this study progresses through three phases, each employing different interviewing techniques based on the situation, including informal interviews, pre-interviews, semi-structured interviews, and structured interviews, totaling 30 participants. In the first phase, through participatory observation and informal interviews, researchers initially integrate into the working environment of J Broadcasting Corporation, gaining an intuitive understanding of the daily work and technological applications of journalists. Subsequently, pre-interviews with senior management capture a comprehensive view of generative AI technology's application at the organizational level, laying an empirical foundation for subsequent research and clarifying the specific direction of the research questions.

In the second phase, based on preliminary research, researchers identified "The Drivers and Barriers to the Adoption of Generative AI Technology by Mainstream Media Journalists" as the core issue. A relevant interview outline was designed, and semi-structured interviews were conducted with 15 journalists from various departments and positions within J Broadcasting Corporation. This phase involved an in-depth exploration of driving and hindering factors, collecting rich firsthand data.

Finally, in the third phase, after analyzing and comparing data obtained from the preliminary efforts, it was found that the UTAUT model and TOE framework provide effective theoretical bases for a detailed analysis of the factors influencing journalists' adoption behaviors. To validate and deepen earlier findings while enhancing the representativeness and applicability of the research, the interview outline was refined based on these theoretical frameworks. The sample scope was expanded to include structured interviews with 15 journalists from different regions, media types, and job positions within J Province.

## 5 SELECTION OF INTERVIEWEES

This study rigorously adheres to the principles of scientific sampling to ensure the breadth and representativeness of interview subjects. Initially, stratified sampling and snowball sampling techniques were employed to select 15 representative journalists within the J Province Broadcasting and Television Station, covering diverse departments, positions, ages, and genders. To enhance the comprehensiveness of the research, the sample was subsequently expanded to include an additional 15 journalists from various regions, media types, and positions within J Province, achieving data saturation. Throughout the interviews, strict ethical standards were maintained to protect the privacy of participants and to ensure the authenticity and legality of the data.

**Table 1** List of Interviewees

| Code | Gender | Age | Media Type | Position |
|---|---|---|---|---|
| A01 | Male | 43 | Broadcast Station | Senior Editor |
| A02 | Female | 36 | Broadcast Station | News Anchor |
| A03 | Male | 31 | Broadcast Station | News Anchor |
| A04 | Male | 39 | Broadcast Station | Field Reporter |
| A05 | Male | 31 | Broadcast Station | Editor, Columnist |
| A06 | Male | 30 | Broadcast Station | Photojournalist |
| A07 | Male | 35 | Broadcast Station | Broadcast Technician |
| A08 | Female | 35 | Broadcast Station | Media Analyst |
| A09 | Female | 36 | Broadcast Station | Technology Correspondent |
| A10 | Male | 30 | Broadcast Station | Investigative Journalist |
| A11 | Female | 28 | Broadcast Station | Political Reporter |
| A12 | Female | 40 | Broadcast Station | Editor |
| A13 | Male | 31 | Broadcast Station | Camera Operator |
| A14 | Female | 32 | Broadcast Station | Technology Correspondent |
| A15 | Male | 30 | Broadcast Station | Editor |
| B01 | Female | 29 | Multimedia | News Editor |
| B02 | Male | 30 | Newsroom | Producer |
| B03 | Female | 24 | Newsroom | News Anchor |
| B04 | Male | 27 | Newsroom | Field Reporter |
| B05 | Female | 36 | Multimedia | News Editor |
| B06 | Male | 32 | TV Broadcaster | Broadcast Technician |
| B07 | Female | 28 | Newsroom | Political Reporter |

| | | | | |
|---|---|---|---|---|
| B08 | Male | 40 | Broadcast Station | Editor |
| B09 | Female | 30 | Broadcast Station | Technology Correspondent |
| B10 | Male | 35 | TV Broadcaster | Broadcast Technician |
| B11 | Female | 33 | Multimedia | Broadcast Technician |
| B12 | Male | 38 | Multimedia | Editor |
| B13 | Female | 37 | Newsroom | Producer |
| B14 | Male | 26 | Newsroom | Field Reporter |
| B15 | Female | 32 | Broadcast Station | Technology Correspondent |

## 6 RESULTS

The interviews primarily explored journalists' attitudes towards generative AI technology, their practical applications, and their reflections on human-machine relationships. The findings indicate that in terms of technical understanding, most journalists are only familiar with specific large language model products, with this familiarity largely stemming from trial usage or demonstrations by others. However, all interviewees acknowledged the potential of generative AI technology, agreeing that embracing new technologies is an inevitable path for industry development.

In terms of willingness to adopt generative AI technology, the interviewed group exhibited a generally low inclination, with significant attitudinal differences across departments. Those in the product, design, and technology departments showed the most interest. During the interviews, A04 from the product development department elaborated on the substantial potential of generative AI to enhance product innovation and optimize user experiences, predicting that the technology would become deeply integrated into all future products. Conversely, journalists from the editorial department were generally cautious, expressing doubts about its ability to meet the stringent demands of news work. "I think the accuracy of the content generated by this technology is at most 70%, which is intolerable for our journalistic work," stated B02, an editor.

Regarding adoption behavior, most journalists initially embraced the technology between late 2022 and early 2023, when the related products were newly launched and highly popular. However, interest waned shortly thereafter. Only a few journalists continued to use the technology persistently, mainly focusing on handling routine, repetitive tasks, with little motivation to explore the technology's full potential. A very small number of journalists displayed high enthusiasm for generative AI technology and maintained ongoing interest. "The development of generative AI technology has exceeded the imagination of most people; it can now achieve many things that ordinary humans cannot," noted B14, a photojournalist. Additionally, younger interviewees generally exhibited higher tolerance, acceptance, and frequency of use compared to their older counterparts, who often demonstrated greater professional confidence during interviews, believing that AI is currently unable to perform the core tasks of a journalist.

## 7 DISCUSSION

### 7.1 Driving Factors for Journalists' Technology Adoption

Interviews revealed that a dual drive of social influence and curiosity prompts journalists to initially adopt generative AI technology. Most respondents reported that their first encounter with and use of the technology were motivated by news, online information promotion, and positive recommendations and demonstrations from colleagues, friends, or leaders. This dissemination of information via social networks not only enhanced the credibility and attractiveness of the new technology but also accelerated its popularity and application among journalists through mechanisms of group identity and imitation.

Performance expectancy is the core driving force behind journalists' continued adoption of generative AI technology, with most interviewees expressing hopes of improving their work efficiency through its use. Additionally, effort expectancy serves as a catalyst for journalists' ongoing engagement with generative AI technology. Unlike traditional media tools, generative AI allows for interaction via natural language, greatly simplifying operational procedures and enabling even journalists without technical backgrounds to easily get started. This low-threshold user experience not only reduces learning costs and time investment but also enhances journalists' confidence in the technology and their willingness to adopt it. "I find it very easy and hassle-free; you just put the manuscript in, and it's proofread in no time," said B01, an editor.

Consideration of facilitating conditions does not directly impact journalists' willingness to adopt generative AI technology, but it significantly influences their preferences for specific technological products. For instance, journalists tend to favor domestic large language models like Wenxin Yiyan over more functionally superior but legally challenging-to-access models like ChatGPT. This choice reflects the rational decision-making and cautious attitude of journalists in the technology adoption process and underscores the significant impact of the policy environment on technology preferences.

### 7.2 Barriers to Journalists' Adoption of Technology

The factors influencing journalists' willingness to adopt technology can be explored at the organizational, operational, and ethical levels. Organizational factors significantly impact initial adoption, while operational and ethical factors primarily influence the willingness to continue adopting the technology.

***7.2.1 Inverted pressure structure***

Within broadcast organizations, the distribution of pressure forms a unique inverted pyramid structure, where the goal-oriented pressure faced by top management significantly diminishes as it trickles down, leading to a divergence in technological innovation needs across different organizational levels. This phenomenon is closely linked to the hierarchical structure, unique organizational culture, and existing management practices of traditional media organizations. Middle and upper management, as decision-makers, not only set strategic goals and make significant decisions but also face multiple pressures such as market competition, performance metrics, and shareholder expectations. Consequently, they are often more proactive in seeking technological innovations to address external challenges. "For the news industry, technology directly relates to a media organization's dissemination efficiency and competitive market presence, and generative AI represents a critical new opportunity for us," explained A01, Operations Director. However, as power and pressure decrease across organizational levels, frontline journalists focus more on executing specific tasks, prioritizing whether new technology can practically enhance work efficiency rather than its strategic significance. "I haven't felt AI technology making a big difference yet; I just use it as a decent search tool," mentioned political journalist A07. Additionally, the distortion and delay in information transmission between levels further mislead staff about organizational strategic goals, weakening their motivation to adopt new technologies.

***7.2.2 Unreasonable remuneration system***

The design flaws in compensation systems also play a significant role in journalists' lack of motivation to learn and apply new technologies. As Karl Marx described the press as "a literary profession with earnings," monetary incentives are crucial for journalists' professional development. Studies show that perceived fairness in compensation—comparing the economic and non-economic rewards provided by organizations against personal expectations—has a significant positive effect on media professionals' ability to utilize and explore innovative capacities[17]. However, within mainstream media, the work environment and salary levels remain relatively constant, with issues like insufficiently differentiated pay scales, unclear career paths, and ineffective incentives. "In-system incomes are fixed; exceptional abilities don't lead to high salaries, and poor performance doesn't impact unless there are major issues," noted A04 from product development. The disconnect between compensation and work efficacy means that improvements in work efficiency brought about by technological innovation do not translate into corresponding economic incentives, potentially increasing the learning burden on journalists and leading them to adhere to traditional work modes. Therefore, constructing a fair and reasonable compensation system is crucial for fostering innovation and competitiveness in the media industry.

***7.2.3 Operational level factors***

Under the backdrop of media convergence, journalists are increasingly tasked with non-traditional news production roles, such as writing promotional copy and drafting contracts, where generative AI technology can provide substantial support. However, significant differences in domain applicability are a major reason for the varied attitudes towards this technology across departments. Investigative journalist A06 noted, "There are many unofficial classifications of journalistic duties, such as political, economic, or public welfare reporters; or by work style, there are text journalists, undercover journalists, live broadcasters, photographers, etc." Different operational domains vary greatly in task rules and complexity.

In data-intensive and rule-specific domains (such as financial analysis or sports reporting), or tasks like manuscript polishing, grammar checking, and spelling correction, generative AI technology can significantly enhance work efficiency.However, for tasks with higher complexity and uncertainty, generative AI technology shows limitations. Firstly, the knowledge base of generative AI, which relies on existing data inputs, updates slowly and cannot fully meet the timeliness required by news reporting. Secondly, the authenticity of news demands on-site interviews and investigations, which current technologies cannot fully replicate. As undercover journalist A08 repeatedly emphasized, "News is not only about transmitting information but also about engaging emotionally with the audience; it needs warmth and values." The limited ability of generative AI to understand complex emotions still requires the professional integrity and humanistic care that only journalists can provide. Lastly, as conveyors of societal information and opinion leaders, the content, value orientation, and ideological delivery of news media are crucial. Current technologies are not yet capable of fully understanding and integrating the complex value systems and ideological frameworks that media carry. "Chinese media have strong value attributes and ideologies, and the outputs from artificial intelligence definitely do not align with our directional needs," stated A06, an investigative journalist.

***7.2.4 Ethical level factors***

Currently, content production with generative AI technology primarily adopts a hybrid creation model where humans provide creativity and machines enhance expression, playing a key role in content generation. However, the legal status of machines remains undetermined, leading to complex issues regarding copyright ownership[18]. Most journalists, wary of potential copyright disputes brought about by this technology, exhibit caution and concern. "It's still a big controversy whether the content belongs to the user or the AI company, so to avoid unnecessary trouble, I use it less," mentioned A04 from product development. Due to the unique nature of their work, journalists are particularly cautious about copyright issues to avoid potential infringement risks and legal disputes. Moreover, from an information security perspective, the widespread application of generative AI technology inevitably involves extensive data processing and storage. In this process, data security and privacy protection remain major concerns for journalists. "Domestic software

is still in continuous improvement, and while foreign ones are more mature, I'm worried about data leaks and privacy breaches," shared A01, Operations Director. Especially in a globalized context, cross-border data flows may increase the risk of data leaks, necessitating greater caution from journalists when making decisions about technological innovation.

## 8 CONCLUSION

Generative AI technology is not only an inevitable path in the context of media convergence but also a crucial engine driving deep media integration. Although generative AI currently has many limitations, interviewees remain optimistic about its future development. Investigative journalist A08 described it as an evolving organism: "As it ingests more and higher-quality data, I believe that in the future, you will only need to click a mouse to produce a beautiful article." Therefore, optimizing the AI usage environment and experience through exogenous measures can effectively promote journalists' willingness to adopt the technology, thereby achieving the goal of efficient human-machine collaboration.

### 8.1 Improving Goal Transmission Methods and Optimizing Compensation System Design

To address the irrational pressure structure within media organizations, senior managers should actively take a leading role by formulating clear strategic plans and conveying the importance and expectations of new technologies. This ensures that employees at all levels deeply understand and respond positively to these advancements. Simultaneously, multi-level mobilization and training should be organized to build consensus on execution, emphasizing the crucial role of new technologies in improving efficiency and competitiveness. Establishing a two-way communication mechanism is essential for eliminating cognitive gaps, actively collecting feedback from the grassroots, promoting organizational information flow and collaboration, and enhancing employees' confidence and motivation in applying new technologies.

To address the irrational aspects of the compensation system, establishing an incentive-based performance pay system can be considered. For example, introducing performance bonuses, setting reasonable remuneration based on workload, difficulty, and responsibility, and establishing technological innovation rewards to encourage journalists to actively adopt and promote new technologies. Through competitive job selection and pay-for-performance, employees' enthusiasm and innovation capabilities can be stimulated, promoting the widespread adoption and application of new technologies.

### 8.2 Precisely Defining the Scope of Technology Application and Reshaping the New Paradigm of Intelligent News Production

In news production, machines and humans each have their strengths, leading to a complementary coexistence. Machines excel at handling large volumes of structured but tedious tasks, such as information screening and preliminary sorting, while journalists bring creative thinking, news values, and humanistic care to the table, enabling them to conduct in-depth evaluation and optimization of machine-generated content. Therefore, accurately defining the application scope of generative AI technology, avoiding unrealistic expectations, and ensuring its practical application are essential.

Reshaping the news production paradigm requires a global perspective and a redesign of production processes to achieve an organic integration of humans and technology, positioning technology as a powerful assistant rather than a replacement for journalists. By optimizing processes and establishing human-machine collaboration mechanisms, an efficient and intelligent news production ecosystem can be constructed, laying a solid foundation for the innovative development of the news industry.

### 8.3 Deepening Journalists' Human-Machine Collaboration Awareness and Strengthening "Prompt" Usage Training

In the context of intelligent news production, deepening journalists' awareness of human-machine collaboration is crucial. Journalists need to recognize the supportive role of generative AI, understand their leading position in news creation, and work closely with technology to enhance work efficiency and quality. Media organizations should intensify training for journalists on effective "Prompt" usage. Given the critical impact of "Prompts" on the output quality of AI models, training should focus on designing clear and effective instructions to guide the model in generating content that aligns with human expectations. Teaching techniques for optimizing model parameters and setting reasonable instructions can help reduce data bias and algorithmic limitations, thereby enhancing the accuracy and efficiency of generative AI in news production.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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# ENGINEERING DOCUMENT PRODUCT LINE FOR KNOWLEDGE MANAGEMENT

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**Abstract:** In order to realize the automation of engineering documents and improve the efficiency of engineering document writing, it is necessary to solve the existing problems of document automation technology based on knowledge management and document automation technology based on content management. Based on the theory of document product line, combined with the theory of knowledge management system, the following results are obtained : Firstly, based on the dual life cycle model of document automation, it is adjusted to make it more suitable for engineering knowledge modeling scheme. Secondly, refer to the model-driven software development architecture, and drive the development of core resources of engineering documents through the evolution of models. Finally, according to the product line theory, an engineering document product line is designed to realize the automation of engineering documents.
**Keywords:** Knowledge management; Engineering document; Document automation

## 1 INTRODUCTION

Engineering documents refer to the documents used to record and manage the information of each stage of the project in the fields of construction, machinery, electronics, computers, etc., and are also the core data of the project[1]. Compared with general documents, engineering documents have the following characteristics: (1) comprehensiveness and authenticity; (2) Inheritance and timeliness; (3) Dispersion and complexity. The factors affecting the engineering project in the engineering document are strong in stages, and accompanied by a large number of engineering information interspersed with each other; (4) Professional and comprehensive. Because of these characteristics of engineering documents, its writing task is more difficult than general documents[2-4]. The arrival of the era of electronic information makes the transmission and sharing of data information easier. The emergence of computers and electronic documents also reduces resource consumption, but the cost and efficiency of manpower are still a difficult problem in the preparation of engineering documents. In this case, in order to solve the problem of labor cost in engineering documents and improve work efficiency, scholars have carried out research on document automation technology[3].
Document automation refers to the technology of using computers to automatically collect data and generate predefined format documents. It is the design of systems and workflows that help create electronic documents[4-6]. Document automation technology first appeared in the 1970s[7]. The original purpose is to save the huge manpower spent on manually filling out a large number of duplicate documents. The core content is to write electronic documents through predefined templates. With the rapid development of science and technology, the following document automation technology can be roughly divided into two categories : document automation technology based on content management and document automation technology based on knowledge management[8]. Document automation based on content management is a technology that binds document content to specific objects and further customizes document templates. The document automation technology based on knowledge management is essentially the documentation of knowledge, that is, how to express explicit knowledge and tacit knowledge in a visible form in the document.
At present, there are two main problems in the automation of engineering documents. The relatively mature document automatic generation technology based on content management cannot meet all the special requirements of engineering documents, and is not suitable for the automatic generation of engineering documents with high complexity[9]. The document automation technology based on knowledge management, which is more suitable for engineering document automation, is lacking in the development of document productization and technology industrialization, and the quality of generated documents does not meet the quality requirements of engineering documents[10].Therefore, the goal of this study is to design an engineering document product line based on knowledge management on the basis of knowledge management system technology and document product line technology related to document content management.

## 2 ENGINEERING DOCUMENT PRODUCT LINE FOR KNOWLEDGE MANAGEMENT

The implementation process of engineering document automation framework based on engineering document automation is also a dual life cycle model, which can be divided into two parts: domain engineering and application engineering. Domain engineering includes three stages: domain analysis, feature modeling and core resource

development. Application engineering includes three stages: application analysis, core resource selection and workflow generation. Knowledge and information are transferred between domain engineering and application engineering through knowledge models such as document domain feature model, template class and node class. The evolution of knowledge model promotes the operation of engineering document product line and the automatic generation of engineering documents. Therefore, this paper will also start from the two stages of domain engineering and application engineering when analyzing and introducing the evolution process of engineering document product line and knowledge model(See Figure 1).

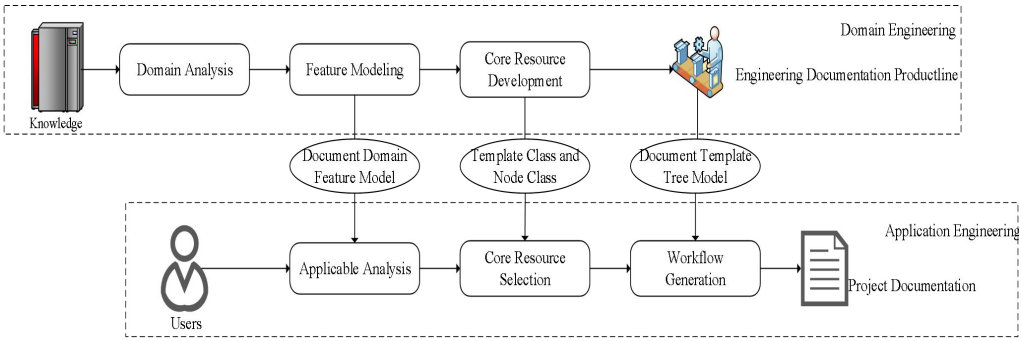


**Figure 1** Engineering Document Automation Framework Based on Engineering Document Product Line

## 2.1 Domain Engineering

The domain engineering stage of the engineering document product line is shown in Figure 2, which consists of three stages : domain analysis stage, feature modeling stage and core resource development stage. Among them, the feature modeling stage is the core stage of domain engineering, which is divided into three steps: knowledge analysis, feature analysis and product analysis. The main tasks of the whole domain engineering stage are: (1) Analyze the engineering knowledge of the specified engineering field and establish the engineering field model; (2) The feature modeling of the engineering domain model is carried out to realize the transformation to the document domain feature model. (3) Develop template class and node class according to the document domain feature model, and use it as the core resource to design the engineering document product line.

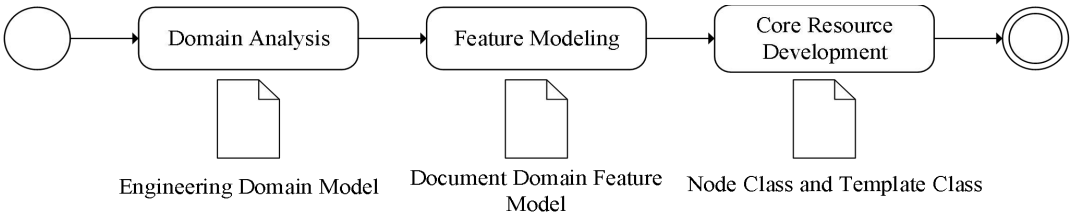


**Figure 2** The Domain Engineering Stage of Engineering Document Product Line

### *2.1.1 Domain analysis*

Domain analysis refers to a clear definition of the scope of engineering knowledge of the document product line, that is, which engineering knowledge belongs to the field and which engineering knowledge does not belong to the field. The main task of the domain analysis phase is to classify the engineering knowledge of a specific engineering field through domain analysis, divide the entire engineering domain knowledge into several knowledge domains, and establish an engineering domain model. Therefore, the domain analysis stage of the engineering document product line is actually the process of knowledge modeling in the engineering field. The activity diagram of the domain analysis phase is shown in Figure 3. Firstly, the standard files of specific engineering fields are identified and the level and type of standard files are recorded. Then, the knowledge domain and logical constraints are confirmed according to the standard file; after that, the domain analysis of the knowledge domain is carried out. If there is a conflict between the knowledge domains of different standard files in the engineering field, it is necessary to re-identify the standard file after conflict resolution according to the level and type of the standard file; finally, all knowledge domains in the engineering field are connected together through logical constraints to generate an engineering domain model.

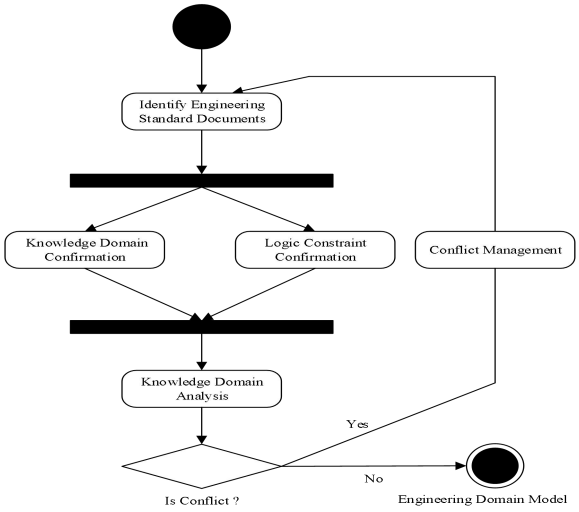


**Figure 3** Domain Analysis Algorithm Activity Diagram of Engineering Document Product Line

### *2.1.2 Feature modeling*

As shown in Figure 4, in the engineering document product line, the domain analysis phase of domain engineering determines the engineering knowledge scope of the engineering document product line, divides the engineering knowledge of a specific domain into several knowledge domains connected with the engineering domain through logical constraints, and establishes the engineering domain model. The engineering domain model contains multiple knowledge domains, and each knowledge domain describes a complete knowledge topic. Therefore, in the knowledge management system, the knowledge link relationship between the engineering domain model and the knowledge warehouse containing multiple knowledge topics is established, and there is an entity relationship between the engineering domain model and the data warehouse. Therefore, the knowledge management system and knowledge warehouse have a great influence on the feature modeling process starting from the engineering domain model.

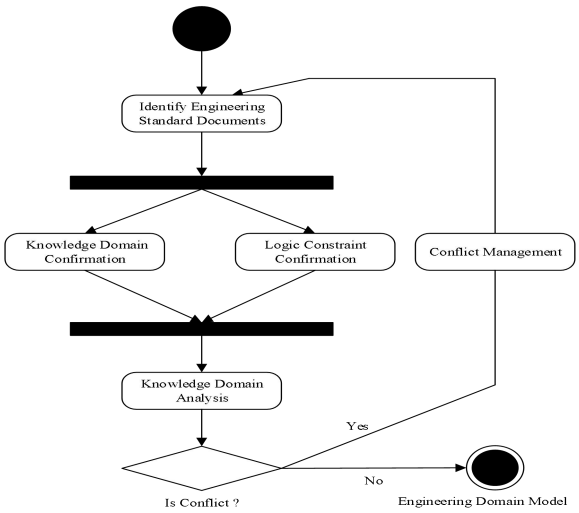


**Figure 4** The Relationship between Feature Modeling and Knowledge Management

The first step of knowledge analysis is the model transformation process from engineering domain model to knowledge element model, which is embodied in the knowledge modeling of the knowledge elements contained in the engineering domain model. In the knowledge management system, the knowledge domain and the knowledge base corresponding to the knowledge topic establish a knowledge link relationship. The knowledge element is the smallest knowledge piece that cannot be decomposed in the knowledge base, and the knowledge element linked to the knowledge domain can be retrieved in the knowledge base. Therefore, in the knowledge management system, the knowledge source of knowledge analysis can be knowledge warehouse. Therefore, the algorithm process of knowledge analysis is divided into four steps: (1) Identify the knowledge topic described by the knowledge domain; (2) Link to the knowledge base of the corresponding knowledge topic; (3) Identify the knowledge element contained in the knowledge base, and re-retrieve it from the knowledge base if the knowledge element and knowledge domain do not exist; (4) The knowledge element model is obtained by connecting the knowledge elements together through the knowledge element link.

The second step of feature analysis is the transformation process from knowledge element model to document feature element model, which is embodied in the knowledge modeling of the attributes and operation information contained in the knowledge element model. There is a link between the attributes and operations of the knowledge element and the

fact base and rule base contained in the knowledge base. By identifying the indexing information of the knowledge element, the information of the corresponding knowledge slice can be retrieved in the knowledge base. Therefore, in the knowledge management system, the knowledge source of feature analysis can be fact base and rule base. Therefore, the algorithm process of feature analysis is divided into four steps: (1) Identify knowledge element indexing information; (2) Retrieve the attribute and operation information of knowledge element in the corresponding fact base and rule base according to knowledge indexing; (3) Document features and feature constraint relations are defined according to the retrieved knowledge element information; (4) Identify the binding state of document features and generate the document feature meta-model. If the nature of the document feature meta-model is not satisfied, the error feature information is reported and the next knowledge element is identified.

The third step of product analysis is the transformation process from document feature meta-model to document domain feature model, which is embodied in further knowledge modeling of product attributes contained in document features defined by document feature meta-model. According to the relevant theory of document product line, the engineering document product line regards the document as a combination of document representation and document content, so the product attributes of the document are mainly reflected in both content and representation. In the process of product analysis, the document domain feature model inherits and strengthens the product attributes of the document feature meta-model, and divides the document domain features into document content features and document representation features. Therefore, the algorithm process of product analysis is divided into four steps: (1) Confirm the document feature element model; (2) Identify the document features and feature constraint relations defined in the document feature meta-model; (3) According to the product attributes contained in the document features, namely content and representation, the document content features and document representation features are defined respectively, and the feature constraint relationship is further divided into refinement relationship and cross-tree constraint relationship according to semantics; (4) All document content features and document representation features are connected together through the newly defined feature constraint relationship until the document feature model can fully describe all the document features in the document feature meta-model.Finally, a more ' product ' document feature model is obtained.

***2.1.3 Knowledge modeling based on dimension model***

As shown in Figure 5, the main task of the core resource development phase of domain engineering is to customize and develop the corresponding node components and template components for all the document representation features in the document domain feature model obtained in the feature modeling phase. Their knowledge information is stored in the core resource library in the form of node classes and template classes.

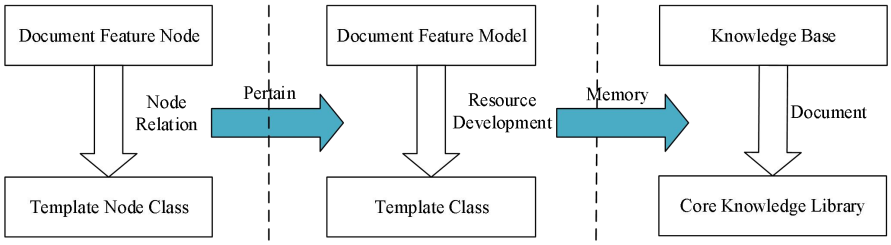


**Figure 5** The Relationship between Core Resource Development and Knowledge Management

The algorithm of core resource development is shown in the figure, which can be divided into five steps: (1) Identify the root feature of the document domain feature model and determine the type of the template class; (2) Retrieve the corresponding document content and representation information from the document content features and document representation features of the document domain feature model; (3) According to the knowledge information of document domain features, the node dimension value and knowledge content type of template node class are determined; (4) By expressing the node dimension value and node knowledge content, the corresponding template node class is generated; (5) The template node class is used to completely replace the document domain features in the document domain feature model to obtain the corresponding template class.s shown in Figure 5, the main task of the core resource development phase of domain engineering is to customize and develop the corresponding node components and template components for all the document representation features in the document domain feature model obtained in the feature modeling phase. Their knowledge information is stored in the core resource library in the form of node classes and template classes(See Figure 6).

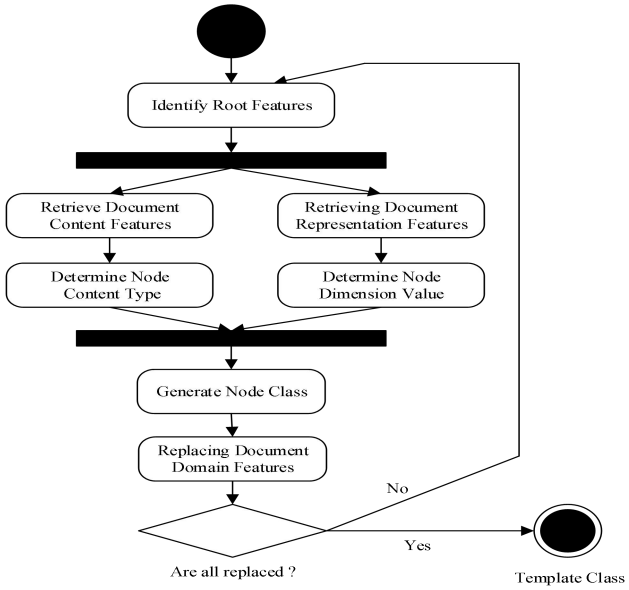


**Figure 6** Core Resource Development Algorithm Activity Diagram

## 3 APPLICATION ENGINEERING

The application engineering phase of the project document product line is shown in Figure 7 which is composed of three stages in turn, namely, application analysis, core asset retrieval, and workflow generation. The main tasks of the entire application engineering phase are: (1) Through application analysis, select the appropriate document features based on the document domain feature model to obtain the document application feature model; (2) Search in the core asset library according to the document application feature model, select the corresponding template class and node class; (3) Through the selected template class and node class and document application feature model, design document creation workflow.

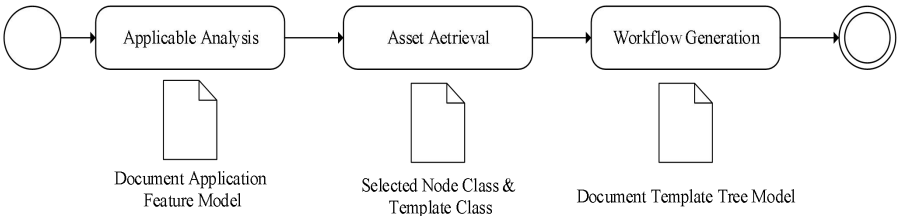


**Figure 7** The Application Engineering Stage of Engineering Document Product Line

### 3.1 Applicable Analysis

The main task of application analysis is to re-edit the document domain feature model by feature selection according to the specific engineering application requirements. The actual performance is the process of pruning the document domain feature model to obtain the document application feature model. The algorithm of application analysis is shown in activity diagram 8, which can be summarized into five steps: (1) According to the information of the target engineering field, the document domain feature model is obtained from the knowledge base and imported; (2) Identify the document content features in the document domain feature model and determine whether the features are in a binding state; (3) Identify all the feature constraint requirements of document features, and prune them according to specific application requirements; (4) Confirm the relative position of the retained document content features, and obtain the document representation information of the corresponding position; (5) Reedit the document representation features through the editor, connect the document representation features with all the document content features at the corresponding location, and reorganize the new document application feature model(See Figure 8).

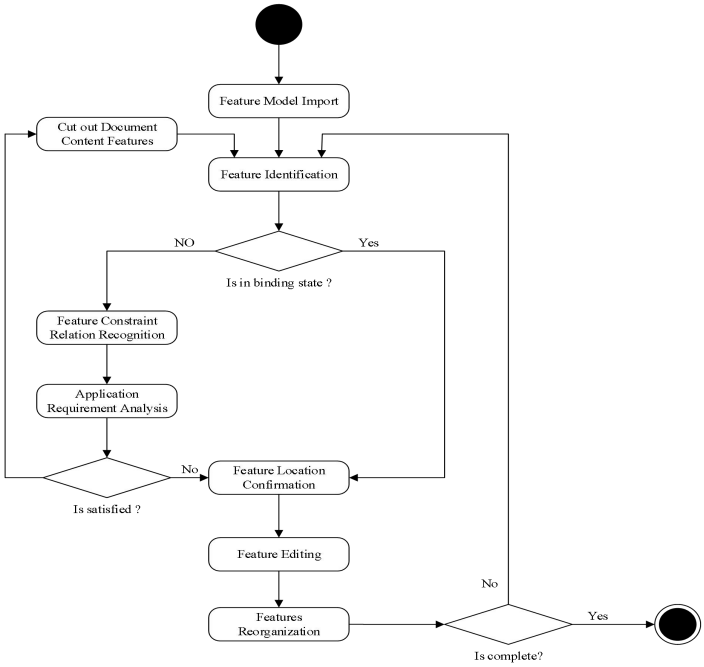


**Figure 8** Application Analysis Algorithm Activity Diagram

### 3.2 Applicable Analysis

The core resource selection process in the application engineering phase is the process of generating a document template based on the document application feature model, and the document template is stored in the form of a document tree model. The activity process of the document editor to edit and generate the document template is shown in Figure 9. By judging the feature type of the input document template feature model, the document structure, feature depth and brother number information are obtained from the coding information of the document template representation feature, and the content type is obtained from the brother document content feature, and then the corresponding document template tree node is re-encoded according to the obtained data information.

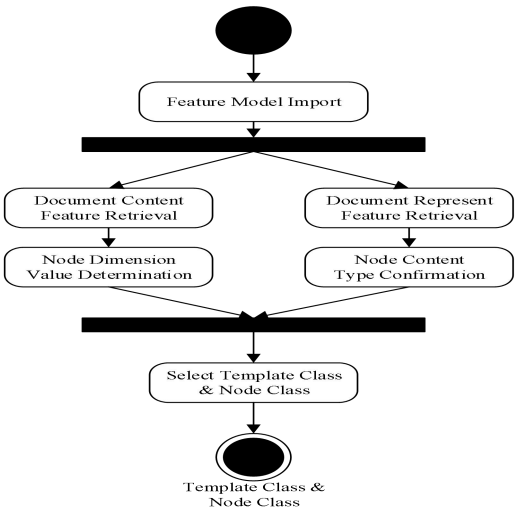


**Figure 9** Core Resource Selection Algorithm Activity Diagram

Step (3) of feature analysis, that is, the definition and specification of document features and feature constraints, is the key to feature analysis. This is because document features and feature constraint relations are part of the document feature model, and their definitions and specifications are directly related to the content structure and standardization of the document feature model. Therefore, when defining the document features and the relationship with the feature constraints, a parameter is needed as the basis for judging the normative definition.

For the document domain feature model, this parameter is the binding state T of the feature. According to the different knowledge situations, knowledge will change, which is because of the dynamic attributes of knowledge. But at a certain stage of the engineering document product line, knowledge is certain, and so are document characteristics. From this point of view, document features have two states in the life cycle of engineering document automation : bound state and unbound state. Therefore, ' whether the feature is in a binding state ' can be regarded as a binary logic proposition, and

the feature name T (a) refers to the variable of the proposition. When analyzing the characteristics of the knowledge element model, according to whether the document features are in a binding state, the knowledge information described by it can be further divided into common knowledge and variable knowledge to show dominance.

### 3.3 Workflow Generation

The workflow generation process in the application engineering stage is the process of replacing the document features in the document application feature model with the selected template class and node class and generating the workflow created by the document template. From the perspective of knowledge management and model evolution, this process uses XML and its related technologies to realize the documentation of engineering knowledge by transforming the document application feature model into a document template tree model based on XML platform.
Therefore, the algorithm for generating the document template tree model is shown in Figure 10, which can be divided into four steps: (1) Identify the document feature coding information in the document application feature model; (2) If the first two bits of the code are 01, the corresponding node class is found from the core resource library, otherwise the corresponding template class information is retrieved from the core resource library; (3) The document node is generated according to the selected template class and node class information, and the document template tree model is obtained; (4) On the XML platform, the document nodes are captured as element nodes to generate workflow.e core resource selection process in the application engineering phase is the process of generating a document template based on the document application feature model, and the document template is stored in the form of a document tree model. The activity process of the document editor to edit and generate the document template is shown in Figure 9. By judging the feature type of the input document template feature model, the document structure, feature depth and brother number information are obtained from the coding information of the document template representation feature, and the content type is obtained from the brother document content feature, and then the corresponding document template tree node is re-encoded according to the obtained data information.

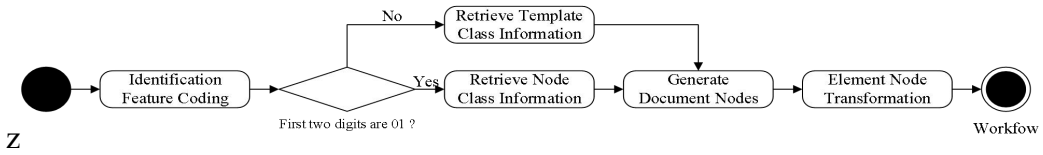


**Figure 10** Workflow Generation Algorithm Activity Diagram

The most important step in the workflow generation process is the generation of the document template tree in step (3). The knowledge logic of this step is shown in Figure11. Refer to the knowledge context modeling of the document template tree, because the document template tree is a top-down hierarchical tree structure, and a template has only one template root node, and the root node stores the relevant information of the template class. Therefore, the node class shared by the outline template class and the chapter template class must be the chapter template root node, and the node shared by the chapter template class and the paragraph template class must be the paragraph template root node. The dotted circle in the figure represents the selected template class and node class, and the circle represents the generated document node. In the process of document template tree generation, according to the selected template class and node class, the corresponding document node instances are generated. These nodes are connected together according to the structure of document features in the document application feature model to form a document template tree. Finally, only in the XML platform, the template node in the document template tree is transformed into the form of XML element node to realize the generation of workflow.

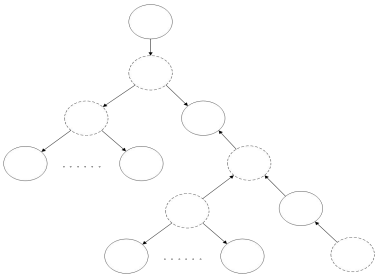

**Figure 11** Knowledge Logic Generated by Document Template Tree Model

## 4 CONCLUSION

Based on the existing research of document automation technology based on knowledge management, this paper analyzes and solves two key problems that need to be solved on the road of industrialization and productization. On the one hand, by designing a multi-level knowledge modeling method based on dimension model and MDA, the product attributes of engineering documents are strengthened, which makes engineering documents more in line with the needs of products. On the other hand, according to the relevant knowledge of the document product line, the engineering document product line based on knowledge management is designed, and the engineering document is generated by

knowledge evolution, which solves the most basic problem in the industrialization of engineering document automation technology. However, these two problems are only two of the many problems encountered on the road to industrialization and productization of document automation technology. While solving these two problems, there are also some new challenges and problems. The future research direction will turn to the following important aspects :

The multi-level knowledge modeling method based on dimension model and MDA indeed strengthens the product attributes of engineering documents. However, in the process of model transformation, knowledge transfer between multiple levels is also more likely to cause the loss and leakage of knowledge information. Therefore, in the future, we will consider introducing relevant information confidentiality methods into the model transformation process.

The industrial generation of document templates can be realized through the engineering document product line driven by knowledge model. However, when the number of parallel users of the engineering document product line is too large, the workflow created by a large number of documents will be blocked and the work efficiency will be reduced. Therefore, in the future, we will consider how to solve the congestion problem caused by concurrent execution of workflows in the engineering document product line.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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# AIR PURIFIER PARTICLE FILTER LIFETIME EVALUATION ALGORITHM FIT FOR OUTDOOR PM2.5 LOW CONCENTRATIONS SITUATION

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**Abstract:** The paper aims to build an air purifier particle filter lifetime evaluation algorithm fit for outdoor PM2.5 low concentration. Current, GB/T 18801 standard gives the evaluation of particle filter lifetime base on outdoor PM2.5 concentrations based on CCM value of particle filter. But the formula that givens by GB/T 18801 only fit for outdoor PM2.5 concentrations that is higher than 58 ug/m^3. When outdoor PM2.5 concentrations is low than this value the result of filter lifetime will be negative value. However, in real case, outdoor PM2.5 concentration in most area is lower than 58 ug/m^3. Developing the particle filter lifetime evaluation algorithm fit for outdoor PM2.5 low concentrations situation is needed. The paper gives the new aspect of the calculation that considers low PM2.5 concentration outdoor to catch the real case of filter lifetime. And conduct the test to verify the results.
**Keywords:** Air purifier; Particle filter; Low pm 2.5 concentration; Filter lifetime

## 1 INTRODUCTION

Ambient air pollution remains a troublesome problem in many developing countries. PM2.5 is seriously exceeding the recommended thresholds in many regions [1-2]. PM2.5 refers to particulate matter that is less than 2.5 micrometers in diameter. These tiny particles can pose significant health risks due to their ability to penetrate deep into the lungs and even enter the bloodstream. Exposure to PM 2.5 will cause respiratory Issues: PM2.5 can cause or exacerbate respiratory diseases such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD). Controlling indoor air quality and mitigating the PM2.5 concentrations is beneficial to human health. Using air purifier is common and useful way to realize low PM2.5 concentrations inside the room. Particle filter is key component in air purifier to remove the PM2.5 in the air. Although, with the capture of particle on the filter, the lifetime of the particle filter is limited. GB/T 18801 give a method to test CCM (cumulated clean mass) of the filter and calculate the particle filter lifetime based on CCM data got from test [3-4]. But the formula given by GB/T 18801 is not fit the relative lower PM2.5 concentration situation. When outdoor PM2.5 concentrations is low than this value the result of filter lifetime will be negative value. Base on the World Air Quality report given by IQ AIR in 2023, only 2 cities out of 134 cities has average annual PM2.5 concentration outdoor higher than 58 ug/m^3 [5]. Hence, the calculation in GB/T 18801 cannot be used in most of area to give a relative reasonable filter lifetime. In this paper, the real outdoor PM2.5 concentration is considered to impact the indoor steady state PM2.5 concentration according to air purifier PCADR (particle cleaning air delivery rate) and served area. Based on this fact, the new calculation particle filter lifetime evaluation algorithm is more reasonable and will not give output of filter lifetime in any PM 2.5 concentrations outdoor. And test on used filter in low PM 2.5 concentration area also be conducted to verify the correction of the formula.

## 2 METHODS

### 2.1 Laboratory Experiments

Two different air purifiers (AP#1, AP#2) with particle filter were tested. The information of their corresponding test data is shown in Table 1.

**Table 1** Air Purifier Information

| | Raw material of particle filter | New filter PCADR(m^3/h) | CCM (mg) |
|---|---|---|---|
| AP#1 | H13 | 226.2 | 7600 |
| AP#2 | H13 | 383.18 | 12000 |

#### *2.1.1 Air cleaners: chamber CADR and CCM tests and lifetime calculations*

The air cleaners were tested against cigarette smoke for several times for the CCM tests according to GB 18801-2022 [6-7]. In each challenge,30–100 cigarettes were lighted with a pressured cigarette lighter to guarantee the complete combustion and stability of dust generation in a 30 m3 stainless steel chamber. Furthermore, the smoke mass concentration was measured after lighting the cigarettes for 10 min to ensure an accurate estimation of the emitted smoke mass. The smoke (20 mg/m3 ~70 mg/m3) was loaded to the air purifier when the air cleaner ran at the maximum airflow, then its CADR of the total particulate matter (d > 0.3 μm) was measured after the loading process according to the standard [8]. CADR is defined as follows in laboratory tests:

CADR = V × (ke − kn) m3 / h

The CADR and CCM data tested also listed in the table 1. the CCM and PCADR is the key parameter to calculate filter lifetime. The served area based on GB 18801-2022 is listed in below formula (formula 1).

$$\text{Severed area (m^2)} = \text{CADR} * 0.07\sim0.12. \tag{1}$$

In GB/T standard the formula that transform CADR and CCM to filter life is listed.

Particle filter lifetime calculation formula(formula 2)

$$M_{AC} = [k_v \times P_p \times C_{out} - (k_0 + k_v) \times C_t] \times S \times h \times t \tag{2}$$

MAC is CCM value of the air purifier. In above formula. 't' is the filter lifetime.

In the GB/T 18801-2022, the Ct is considered as 35 ug/m^3 (constant value). But the Ct is variant with CADR and served area as well as Cout. Hence, when Cout is lower than 58 ug/m^3. We will get negative value of filter lifetime in above formula.

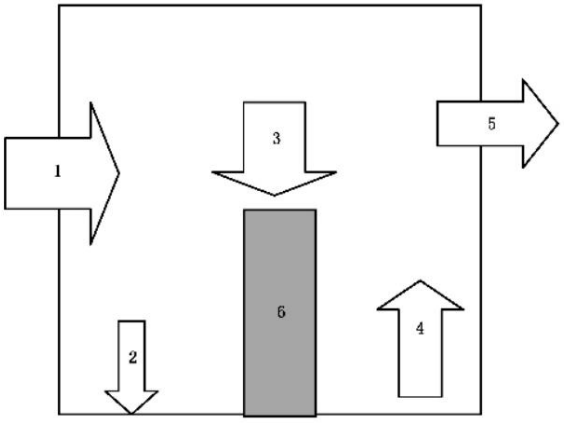
### 2.2 Field Investigation

2 air purifiers were run in Stockholm (capital of Sweden) in 2022. The running time is for 1 year. Runing time for AP1#1 is 16 months. Running time for AP#2 is 12 months. According to AQI report from IQAIR. After running we check the remained PCADR of 2 air purifiers to check its lifetime.

The average PM2.5 concentration outdoor of Stockholm is 6.2 ug/m^3. Current GB/T 18801 standard consider balance concentration in the room is always 35 ug/m^3. Which is not suitable for this situation. We will get the filter lifetime as negative value. Hence, we need to consider the Ct as variant according to real situation.

Indoor particle pollutant transmits process model is shown in below Figure 1.

**Figure 1** Indoor Particle Pollutant Transmits Process Model




1. The particle pollutant from outdoor to indoor due to ventilation
2. Natural decay of particle pollutant.
3. Particle concentration removed by air purifier
4. Particle concentration generated indoor.
5. The particle pollutant emission from indoor to outdoor.
6. Air purifier.

Particle pollutant mass conservation differential equation (3) (E' is 0 which means we are not consider point 4)

$$\frac{dC}{dt} = P_p k_v C_{out} + \frac{E'}{S \times h} - (k_0 + k_v)C - \frac{Q}{S \times h} \times C \tag{3}$$

When **dC/dt= 0**, we can get Ct which is the **stable particle concentration** in the room after Air purifier running for long time in formula 4:

$$C_t = \frac{P_p k_v C_{out} + \frac{E'}{S \times h}}{k_0 + k_v + \frac{Q}{S \times h}} \tag{4}$$

Kv : Ventilation rate of building. 0.6
Pp : Penetrating coefficient.0.8
Cout: Particle concentration outdoor
K0: Natural decay rate of particle 0.2
Ct: Particle concentration @ time t
S: Area of room
h: Height of room
t : Running time of air purifier
E': Particle concentration generated indoor
Q: CADR of the air purifier

## 3 RESULT

We tested the remained PCADR after running certain time in Stockholm to check the real filter lifetime. Normally, when the PCADR drops to 50% of its initial status we consider the filter lifetime is gone. Table 2 is test result. We assume that filter CADR decay follows linear functions. The AP#1 particle filter lifetime should be 65 months. The AP#2 particle filter lifetime should be 60 months. And Table 3 and Table 4 show the calculation filter lifetime of AP#1 and AP#2, the results show AP#1 particle lifetime is 67.14 months and AP#2 particle lifetime is 61.59 months. The comparison of AP#1 and AP#2 lifetime between real case and calculation is listed in Tabel 5. The deviation is within 3.2% which is acceptable (Table 3-5).

**Table 2** Filed Test Filter Running in Stockholm

| | Run time in Stockholm (months) | New filter PCADR(m^3/h) | Remained CADR PCADR(m^3/h) | Remained CADR percentage | CCM (mg) |
|---|---|---|---|---|---|
| AP#1 | 16 | 226.2 | 198.4 | 87.67% | 7600 |
| AP#2 | 14 | 383.18 | 338.3 | 88.29% | 12000 |

**Table 3** Filter Lifetime Calculation with New Algorithm

| AP#1 | Value | Unit |
|---|---|---|
| Pp | 0.8 | |
| Kv | 0.6 | h-1 |
| Cout | 0.0062 | mg/m^3 |
| K0 | 0.2 | h-1 |
| Q | 222.6 | m^3/h |
| S | 26.712 | m^2 |
| h | 2.4 | m |
| Ct | 0.001 | mg/m^3 |
| t | 24 | h |
| CCM | 7600 | mg |

| | | |
|---|---|---|
| Day | 2042 | day |
| Filter lifetime | 5.60 | Year |
| Filter lifetime | 67.14 | Month |

**Table 4** Filter Lifetime Calculation with New Algorithm

| AP#2 | Value | Unit |
|---|---|---|
| Pp | 0.8 | |
| Kv | 0.6 | h-1 |
| Cout | 0.0062 | mg/m^3 |
| K0 | 0.2 | h-1 |
| Q | 383.18 | m^3/h |
| S | 45.9816 | m^2 |
| h | 2.4 | m |
| Ct | 0.001 | mg/m^3 |
| t | 24 | h |
| CCM | 12000 | mg |
| Day | 1873 | day |
| Filter lifetime | 5.13 | Year |
| Filter lifetime | 61.59 | Month |

**Table 5** Filter Filed Test Lifetime Vs Calculation Lifetime

| | Real lifetime (months) | Calculation lifetime (months) | Deviation |
|---|---|---|---|
| AP#1 | 65 | 67.14 | 3.19% |
| AP#2 | 60 | 61.59 | 2.58% |

## 4 CONCLUSION

The paper gives a new filter lifetime calculation model that consider the real balance concentration of particle when air purifier running in a certain size of room. The result shows a good consistency with filed test filter result. But there are still some points missed like inner particle pollutant generation and air flow rate change during the air purifier running. But from engineering execution point of view, the result of the calculation gives enough accuracy of filter lifetime. It improves the defect of GB/T 18801-2022 standard that it can't calculate the low particle concentration outdoor.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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# TEACHING REFORM IN LANDSCAPE ARCHITECTURE MAJOR FROM THE PERSPECTIVE OF PROJECT-BASED STUDIO APPLICATIONS

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**Abstract:** This article focuses on the teaching reform practice and reflections in the Landscape Architecture major at Guangdong Technology College. It utilizes the industry-academia-research ternary system as the framework for teaching reform in the Landscape Architecture major, with the Qingmiao Plan Workshop serving as the platform, and design competitions as the entry point. By analyzing and considering the role and significance of design competitions in teaching, the article explores how to seize this opportunity to deepen the disciplinary teaching model in teaching practice and cultivate students' comprehensive abilities such as social observation and reflection, and problem-solving. Meanwhile, it further discusses how design competitions can promote students' application of learned knowledge in practice and trigger deeper reflections and practical explorations of teaching reform, aiming to provide new ideas and practical guidance for future educational explorations in this field.
**Keywords:** Teaching reform practice; Design competitions; Industry-academia-research; Landscape architecture

## 1 INTRODUCTION

The teaching reform in the Landscape Architecture major is a highly focused research topic in the current field of higher education. Studio project-based learning, as an exploratory pathway for educational reform, offers the possibility of integrating theoretical study, practical application, and innovative capacity, aiming to cultivate interdisciplinary talents who better meet social demands and possess innovative abilities. However, within this emerging educational philosophy, the educational reform of the Landscape Architecture major is still in its initial stage, particularly facing certain bottlenecks in the professional education model. Traditional teaching methods are increasingly difficult to adapt to the current needs for cultivating students in the Landscape Architecture major, lacking in stimulating students' innovative thinking and practical application. The Landscape Architecture major is confronted with unprecedented challenges in addressing the demands of the new era and nurturing talents with practical application abilities. Meanwhile, as a discipline that intersects multiple fields including the harmonious coexistence of humans and nature, society, and humanities, the Landscape Architecture major requires continuous innovation in its education system to satisfy the needs of modern society. Against this backdrop, the educational reform of the Landscape Architecture major needs to shift from traditional knowledge presentation to cultivating students' innovative and practical application abilities. Design competitions, as an effective medium for activating students' thinking and nurturing their innovative abilities, how can they guide students to step out of traditional thinking frameworks and stimulate their abilities to think independently and solve problems? These questions will permeate this study, which aims to provide more innovative thinking logic for the education of the Landscape Architecture major through theoretical analysis and empirical research.

## 2 LITERATURE REVIEW

In the field of educational reform for the Landscape Architecture discipline, due to the constraints of the discipline's characteristics, teaching methods that emphasize theoretical instruction, such as "Flipped Classroom" and "Case-Based Teaching," possess certain limitations. Daniel T. Willingham and Richard E. Mayer, among others, uniformly hold the view that these two teaching methods, by overly emphasizing students' self-directed learning and problem-solving abilities, neglect the issue of cognitive load during the learning process and lack authentic application scenarios, which is detrimental to the cultivation of students' innovative abilities and may not be applicable to all disciplines and all students. For this reason, the studio project-based model, as an alternative teaching method, has garnered considerable attention. It integrates into professional teaching reform through the process of establishing studio platforms, introducing projects, and fostering collaborative participation..

In the 1970s, German physicist Haken introduced the concept of "Synergetics," which he defined as the fusion and interaction among major factors in a large system that transcends individual entities. Early researchers such as David W. Johnson and Roger T. Johnson proposed a theoretical framework for collaborative learning. Their work on cooperative learning and social learning theories played a crucial role in the development of collaborative learning. Early scholars studying synergetics emphasized the importance of cooperation, interaction, and co-construction of knowledge. The concept of "Open Innovation" was first proposed by American management scholar Henry Chesbrough in 2003, in his

book Open Innovation: *The New Imperative for Creating and Profiting from Technology*. This concept emphasized external collaboration and shared innovation, laying the foundation for the later development of collaborative innovation theory. Subsequently, Peter Gloor introduced the term "Collaborative Innovation," highlighting the need for network interaction among subjects, the exchange of ideas, technologies, and information, ultimately leading to the achievement of goals. Studio project-based learning is theoretically grounded in providing industry collaboration or simulated practice, emphasizing the requirements of "collaboration" and "collaborative innovation" to prompt students to apply theoretical knowledge in real-world settings, enhance their practical abilities, and improve their problem-solving skills, thereby fostering the integration and enhancement of innovative capabilities. Donald A. Schön characterized design studios as places for "learning by doing" and "thinking in action" . Kay Brocato believed that design knowledge is formed through the participation, interaction, and co-construction of teachers and students [1]. This cooperative relationship between teachers and students, as well as among students, enables the generation of design knowledge.

Therefore, the workshop model has garnered significant attention as an alternative teaching method. Wang Qianna and others reconstructed the basic ideas and methods of landscape architecture courses by integrating the workshop model [2]. Li Ruidong and his colleagues guided students to use public policy knowledge and Mapping techniques to create community spaces and analyze real social issues through the form of workshops [3]. Neil Kirkwood founded the Ulsan Regeneration Workshop, where teachers from both inside and outside the university jointly guided students in a 14-week renewal and transformation project targeting Ulsan city and its hinterland 4]. However, in the context of landscape architecture, as an engineering discipline that intersects with multiple fields such as engineering, architecture, planning, and management, the role of collaboration and cooperation is particularly emphasized [5, 6]. Workshops focused solely on this discipline fail to achieve the goals of professional integration, collaborative education, and collaborative innovation [7]. Therefore, actively advocating and establishing interdisciplinary partnerships can help create more diverse cooperative opportunities in research, teaching, and practice, bringing numerous benefits to discipline development.

Currently, numerous universities have exhibited diversification and innovation in exploring models and pathways for industry-university-research (IUR) collaboration and multi-university joint cooperation. Universities have actively established partnerships with enterprises, local authorities, and social organizations, conducting a series of activities such as short-term joint design teaching workshops and practical base construction in combination with actual projects. These efforts have jointly carried out scientific research projects, provided students with opportunities for practice and professional guidance, and achieved a series of outcomes in promoting the transformation of scientific and technological achievements, technology transfer, and talent cultivation, thereby exploring deeply integrated IUR models. For example, South China University of Technology has collaborated with the DaST Foundation, Guangzhou Academy of Fine Arts, and foreign institutions to conduct multiple short-term joint design teaching workshops in Jiuxian Village, Guangxi. This project fully utilized local resources for teaching transformation, achieving a joint interaction between design teaching, local education, and rural community building [8]. Tongji University held the "Mapping Joint Workshop" at Chuangzhi Farm, serving a learning and living community through interdisciplinary lectures and plant drift activities [9]. Nanjing Forestry University proposed the "1+2+3" practical teaching model, focusing on the construction of IUR training bases to provide students with a combination of multiple types of off-campus enterprise practice platforms [10]. Additionally, Xuzhou Engineering College adopted the Workshop design studio practical teaching model, integrating teaching methods and practical activities into daily learning [11]. The Gardening major at Gansu Agricultural University has adhered to centering on Lanzhou in the construction of off-campus practice bases, signing cooperation agreements with multiple gardening enterprises and institutions, promoting the development of scientific research projects and student participation [12]. The School of Art and Design at Guangdong University of Technology established a studio in Qingtian Village, exploring the "Qingtian Paradigm" and providing a development path for rural revitalization [13]. The Health Landscape Workshop created by South China Agricultural University and SPI conducted a practice from the perspectives of professional education, industry hotspots, and talent cultivation, resulting in the transformation of materials such as the "Health Community Work Guidelines." During the same period, Guangzhou Academy of Fine Arts also actively co-hosted the Dongguan Water Town Design Workshop based on the TOD concept with SPI, bringing actual projects into professional education to explore the development of water town cities and industry hotspot orientations.

Based on the aforementioned literature, universities have explored reforms in landscape architecture education centered around industry-university-research (IUR) collaboration, yet there are still the following deficiencies: (1) Although these activities emphasize practical teaching and deep integration of IUR, in practical operation, there is a disconnect between teaching content and practical needs. There is an overemphasis on practical operation, which goes beyond simply imparting practical skills and neglects systematic learning and mastery of theoretical knowledge. Furthermore, there is room for enhancement in cultivating students' innovative thinking and social insight abilities; (2) Some activities may lack systematicness and sustainability. Although one-off workshops or practical projects are conducted, the lack of long-term planning and continuous follow-up fails to form an effective learning loop and a long-term mechanism for deep IUR collaboration. Based on the deficiencies identified in the existing literature, this paper studies the practical application of multi-party IUR collaboration and workshop-based practical teaching in the education process of landscape architecture majors, and its possible contributions are as follows: (1) On the basis of maintaining IUR partnerships, a studio project-based model is constructed, combining the characteristics of design competitions to further strengthen and cultivate students' innovative thinking and social insight abilities; (2) A teaching reform in

landscape architecture majors is implemented through the construction of an IUR evaluation and guidance system, exploring effective learning and evaluation mechanisms, as well as a virtuous cycle model for achievement transformation and talent delivery, which serves as a practical test to enrich teaching and learning forms.

## 3 PRACTICE OF TEACHING REFORM IN LANDSCAPE ARCHITECTURE MAJORS UNDER THE INDUSTRY-UNIVERSITY-RESEARCH TERNARY SYSTEM

### 3.1 Case Selection

This paper selects the teaching reform of the landscape architecture major at Guangdong Technology College as a case study, with specific reasons outlined below. Firstly, Guangdong Technology College, established in 2005, is a relatively young private undergraduate institution of applied learning located in Zhaoqing. Its landscape architecture major began autonomous recruitment in 2016, and the first batch of students graduated smoothly in 2020, entering various design institutes, gardening research institutes, and architectural research institutes. With a current student population exceeding 800, the urgency of addressing the specific situation of student cultivation and the transition to social talents is particularly pressing. Secondly, landscape architecture was downgraded from a first-level discipline to a second-level discipline within engineering in 2023. This paper focuses on exploring challenges faced by the teaching application of the landscape architecture major at our institution in utilizing industry-university-research collaboration to achieve effective learning and evaluation, cultivate students' innovative thinking and social insight abilities, and efficiently promote achievement transformation and talent delivery.

### 3.2 Implementation Framework of Teaching Reform Practice

In the practice of teaching reform for the landscape architecture major under the industry-university-research ternary system, the implementation framework can be divided into three main steps. Firstly, establish a mechanism for deep integration of industry, university, and research, collaboratively explore talent training programs, and sign cooperation agreements with enterprises to form deep cooperation with industry enterprises. Secondly, on the basis of maintaining the industry-university-research cooperation relationship, establish an innovative talent platform called the "Green Seed Program" with the goal of talent cultivation. This platform introduces enterprise projects to establish a studio-based project model and incorporates industry-university cooperation mentors. Collaborate with enterprises to determine project implementation processes, design lectures, and other content, balancing the authenticity of research topics and the relevance of teaching, ensuring that teaching content is closely aligned with industry needs and enhancing students' practical abilities. Finally, conduct an evaluation of the effectiveness of the landscape architecture teaching reform. Based on the results of the reform and evaluation, propose improvement suggestions and strategies to effectively promote the teaching reform of the landscape architecture major and achieve the goal of integrated industry-university-research development (Figure 1).

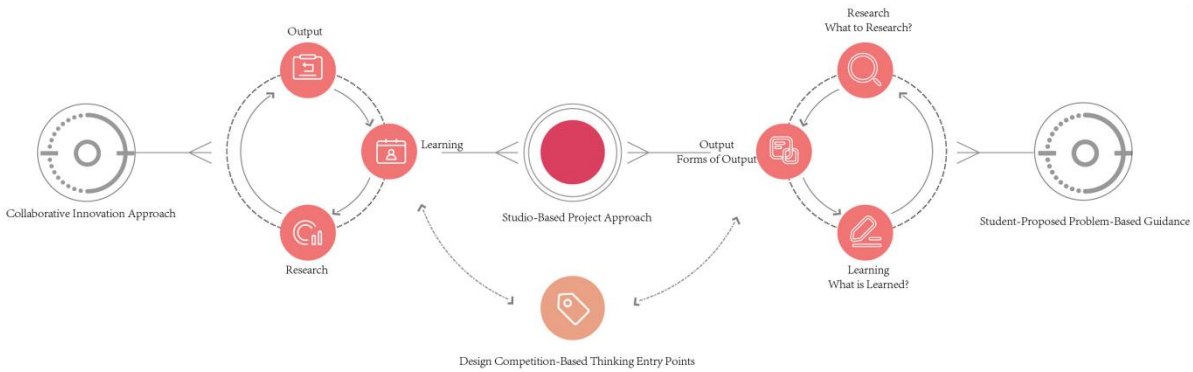


**Figure 1** Implementation Framework

### 3.3 Implementation Process of Teaching Reform Practices

#### *3.3.1 Establishment of a Deeply Integrated Industry-Academia-Research Mechanism*

In the early stages of landscape architecture teaching reform practices under the industry-academia-research ternary system, institutions actively sought to expand job opportunities and signed cooperation agreements with 12 enterprises. They entered these enterprises in the form of teaching management teams from research offices for exchanges, focusing on education and research cooperation in the field of landscape architecture, including the formulation of talent training programs, joint research projects, talent cultivation in institutions, and talent transfer to enterprises. Gradually, a deeply integrated industry-academia-research mechanism was established.

#### *3.3.2 Construction of the Qingmiao Plan Innovative Talent Platform + Introduction of Two Elements*

During the construction of the Qingmiao Plan innovative talent platform, emphasis was placed on the implementation of the "double introduction" strategy, which involves introducing corporate projects to establish a studio-based project mode to stimulate students' innovative thinking, team collaboration, and problem-solving abilities. Additionally, corporate mentors were introduced to provide industry-leading insights and practical guidance, thereby cultivating students' innovative abilities and professional qualities in a comprehensive and multi-layered manner.

#### *3.3.3 Teaching Content Balancing Authenticity of Projects and Relevance to Teaching*

When designing teaching content, consideration was given to balancing the authenticity of projects and their relevance to teaching. Project topics were evaluated by the teaching team to ensure that they aligned with both practical issues and teaching requirements. During the topic formulation process, the teaching experience and professional knowledge of responsible teachers served as fundamental guarantees for formulating practical project tasks. The selected topics were ensured to be close to real life or industry practice, capable of stimulating students' interest in learning and reflecting the applied value of knowledge, while also being closely linked to teaching objectives, curriculum settings, and students' learning needs. This effectively imparted core concepts, principles, and methods, helping students build a systematic knowledge system. By integrating real-life cases with theoretical teaching, students' comprehensive abilities and innovative thinking in facing practical problems were cultivated, providing them with a practical and challenging learning environment.

## 4 EVALUATION OF THE EFFECTS OF STUDIO-BASED PROJECT-ORIENTED TEACHING REFORM

### 3.1 Correlation Analysis

Based on the sustainability of studio-based project-oriented teaching reform, this section analyzes the correlation between 16 indicators: clarity of objectives, degree of goal attainment, innovative thinking, problem-solving abilities, practical experience, practicality of project outcomes, team collaboration, communication skills, project planning and organization, time management, disciplinary integration, breadth of application, project evaluation, project reflection, creative expression, and teacher feedback. The Pearson correlation coefficient is used to represent the strength of these correlations. A detailed analysis in Figure 2 reveals that, in terms of factors influencing the sustainability of studio-based project-oriented reform, four evaluation indicators—clarity of objectives (correlation coefficient of 0.676), project evaluation (correlation coefficient of 0.740), project reflection (correlation coefficient of 0.605), and teacher feedback (correlation coefficient of 0.652)—show significant positive correlations at the 0.01 level, indicating strong and significant positive relationships.

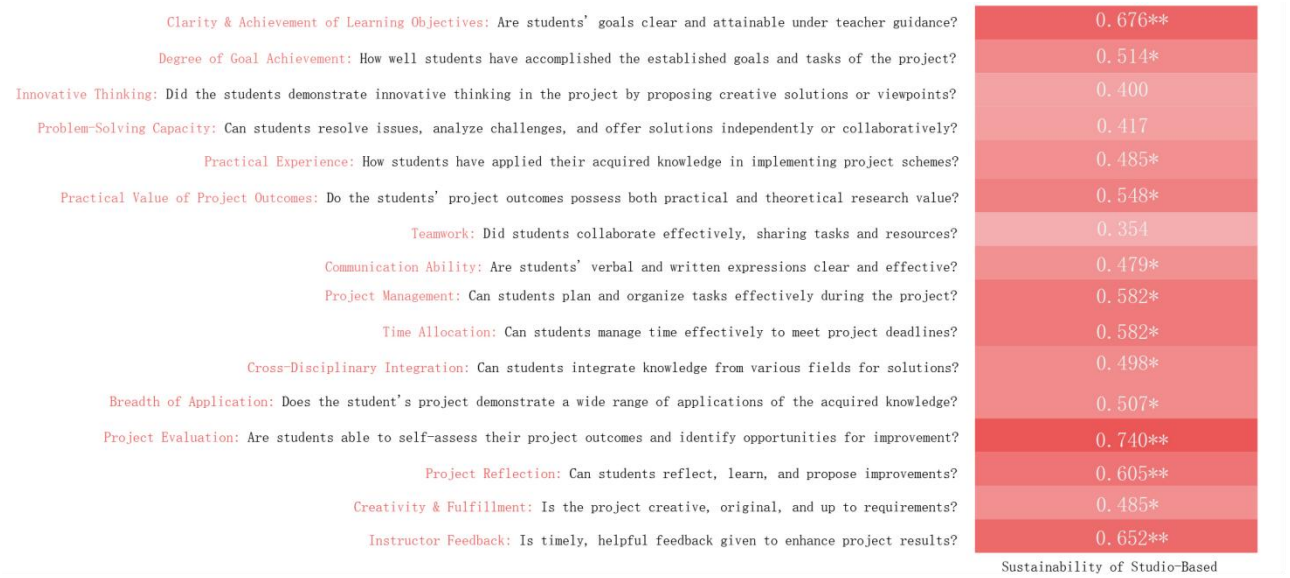


**Figure 2** Correlation Analysis of Sustainability Based on Studio-Based Project-Oriented Teaching Reform

In the sustainability of landscape architecture teaching reform based on studio-based project-oriented learning, clarity of objectives is a core evaluation indicator that is highly focused on during the implementation of this teaching reform. Projects with clear objectives provide directional guidance and lay a solid foundation for subsequent projects by establishing clear work priorities and action directions. The clarity and specificity of goal setting and expected outcomes, as well as their understanding and acceptance by all participants, mean that each participant clearly knows their role and responsibilities within the project, as well as the value and contribution they should make to achieve the project goals. Locke and Latham [14] proposed the "Goal Setting Theory" in their book *A Theory of Goal Setting & Task Performance*, which suggests that specific and clear goals help stimulate individual motivation and form a unified direction. This is particularly important for addressing the current widespread issue of purposeless learning among students. Secondly, the process of project evaluation enables regular objective assessments and feedback on project

progress and outcomes, which helps identify problems in a timely manner and take corrective measures. This process also cultivates students' abilities to "observe problems" and "discover issues", thereby improving execution efficiency. At the same time, regular project reflection based on project evaluation results involves students in deep thinking and summarization of the experiences and lessons learned during the project implementation process. This reflection is not merely a simple review of what happened in the project, but a systematic analysis and consideration of the challenges faced, progress made, and problems encountered during the achievement of project goals. Through project reflection, students can identify the successful factors and causes of failure in the project, explore possible improvement measures, and learn from these experiences and lessons, providing valuable references and guidance for future project implementations. This continuous reflection and learning process helps continuously improve students' self-monitoring and self-regulation abilities.

Additionally, teacher feedback is an indispensable aspect throughout the entire process of studio-based project-oriented reform. Teachers provide feedback on their perspectives, opinions, and suggestions regarding the project implementation process. This feedback can include evaluations and feedback on project design, execution methods, resource support, and learning outcomes. However, in terms of the three stages of "goal setting," "project evaluation," and "project reflection," the intensity of teacher feedback varies. During the "goal setting" stage, teachers provide the most direct feedback on teaching practices for students, helping them better understand the purposes of professional teaching reform and the potential problems and difficulties they may face when participating in reform activities. By actively participating in the teacher feedback process, students can adjust and improve project design and execution strategies in a timely manner, thereby enhancing the sustainability and long-term development capabilities of the project. In the latter two stages, teachers' feedback is more about moderate guidance, and the degree of intervention should be controlled.

### 3.2 Analysis of Relationships Between Other Variables in the Correlation Coefficient Matrix

Based on the above discussions and analyses, we further explore the relationships between other indicator variables in the Pearson correlation matrix for landscape architecture teaching reform (Table 1). Strong correlations exist between creative thinking and creative expression (0.859) and between creative thinking and application breadth (0.793). The close relationship between creative thinking and creative expression indicates that individuals with higher creative thinking tend to perform better in actual creative expression. During this teaching reform process, students with higher creative thinking may be more inclined to apply their creativity to different fields and categories, conducting comprehensive project evaluations to optimize and improve project execution processes and outcomes. Meanwhile, the relationship between social observation and problem-solving can be further studied in relation to other indicators, where it shows only a low correlation with communication (0.316). This suggests that communication skills may not be the most direct influencing factor in the process of social observation and problem-solving, while other factors such as team collaboration (0.704), interdisciplinary integration (0.791), practical experience (0.819), creative expression (0.819), and project reflection (0.750) may be more significant. Issues in a studio project often require the observer to have extremely sensitive social insight to uncover, and landscape architecture is an interdisciplinary field that requires a multidimensional perspective on problems, providing valuable insights and solutions through team collaboration and reaching consensus. Additionally, practical experience provides the team with the skills and knowledge needed to solve problems, thereby enhancing their problem-solving capabilities. In view of this, both problem insight and problem-solving require a high level of interdisciplinary integration ability to reflect creativity in the proposed solutions and engage in reflection and contemplation at every stage of the project process, in order to gain lessons and further improve one's problem-solving abilities.

**Table 1** Pearson Correlation Analysis of Sustainability in Studio-Based Project-Oriented Teaching Reform

| Indicator | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sustainability (1) | 1 | | | | | | | | | | | | | | | | |
| Clarity & Achievement of Learning Objectives (2) | 0.676** | 1 | | | | | | | | | | | | | | | |
| Degree of Goal Achievement (3) | 0.514* | 0.476* | 1 | | | | | | | | | | | | | | |
| Innovative Thinking (4) | 0.400 | 0.472* | 0.607** | 1 | | | | | | | | | | | | | |
| Problem-Solving Capacity (5) | 0.417 | 0.669** | 0.449 | 0.630** | 1 | | | | | | | | | | | | |
| Practical Experience (6) | 0.485* | 0.604** | 0.354 | 0.652** | 0.819** | 1 | | | | | | | | | | | |
| Practical Value of Project Outcomes (7) | 0.548* | 0.518* | 0.666** | 0.632** | 0.692** | 0.603** | 1 | | | | | | | | | | |
| Teamwork (8) | 0.354 | 0.467 | 0.416 | 0.513* | 0.704** | 0.527* | 0.452 | 1 | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Communication Ability (9) | 0.479** | 0.454 | 0.366 | 0.491** | 0.316 | 0.517** | 0.284 | 0.534** | 1 | | | | | | | | | |
| Project Management (10) | 0.582** | 0.567** | 0.617** | 0.510** | 0.411 | 0.436 | 0.559** | 0.602** | 0.718** | 1 | | | | | | | | |
| Time Allocation (11) | 0.582** | 0.324 | 0.617** | 0.420 | 0.518** | 0.546** | 0.658** | 0.708** | 0.595** | 0.714** | 1 | | | | | | | |
| Cross-Disciplinary Integration (12) | 0.498** | 0.607** | 0.591** | 0.606** | 0.791** | 0.608** | 0.768** | 0.641** | 0.522** | 0.614** | 0.713** | 1 | | | | | | |
| Breadth of Application (13) | 0.507** | 0.462 | 0.616** | 0.793** | 0.595** | 0.647** | 0.735** | 0.694** | 0.683** | 0.803** | 0.803** | 0.764** | 1 | | | | | |
| Project Evaluation (14) | 0.740** | 0.618** | 0.588** | 0.686** | 0.613** | 0.693** | 0.627** | 0.405 | 0.548** | 0.424 | 0.545** | 0.696** | 0.580** | 1 | | | | |
| Project Reflection (15) | 0.605** | 0.618** | 0.441 | 0.686** | 0.750** | 0.832** | 0.502** | 0.675** | 0.548** | 0.424 | 0.545** | 0.569** | 0.580** | 0.846** | 1 | | | |
| Creativity & Fulfillment(16) | 0.485** | 0.604** | 0.486** | 0.859** | 0.819** | 0.750** | 0.603** | 0.771** | 0.517** | 0.546** | 0.546** | 0.722** | 0.796** | 0.693** | 0.832** | 1 | | |
| Instructor Feedback (17) | 0.652** | 0.536** | 0.018 | 0.191 | 0.285 | 0.398 | 0.480** | 0.323 | 0.328 | 0.369 | 0.369 | 0.325 | 0.426 | 0.414 | 0.414 | 0.398 | 1 | |

* $p<0.05$ ** $p<0.01$

The above content merely interprets the indicators with strong significance, but it should not overlook the special significance of low-correlation indicators in the process of this teaching reform. The correlation between teacher feedback and the other 16 indicator variables is generally low. Among them, the correlation coefficients between teacher feedback and the three variables of innovative thinking, creative expression, and social observation and problem-solving are 0.191, 0.398, and 0.285, respectively, which are close to zero and statistically insignificant. Although from a statistical perspective, there is almost no linear relationship or research significance between them, this is not the case in the context of this landscape architecture teaching reform. Teacher feedback in student studio projects is limited in terms of intervention, which suggests that landscape architecture teaching has begun to shift from the traditional "what content does the teacher think should be taught to students?" to the "what do students want to learn?" approach to teaching and learning. By establishing and guiding learning goals and tasks, students are provided with more space for active learning and thinking, rather than the teacher merely imparting knowledge in a superimposed manner (Figure 3). This is a practice that enriches the forms of teaching and learning.

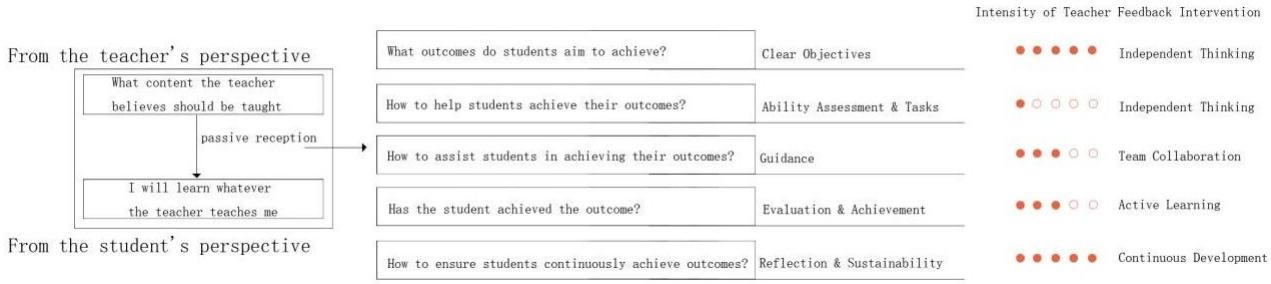


**Figure 3** Transformation Model of Teaching Methods and Intensity of Teacher Feedback Intervention

Therefore, by deepening the understanding of the influencing factors and mechanisms among the indicator variables in the Pearson correlation matrix related to the teaching reform of landscape architecture, we can provide more effective guidance and support for the development of individuals and organizations.

## 5 EVALUATION OF TEACHING REFORM EFFECTIVENESS

### 4.1 Feedback Analysis of Participation Process

As illustrated in Figure 4, questionnaire data has revealed students' exceptional performance in projects related to innovative thinking and problem-solving abilities. Specifically, more than one-third of students (38.89%) strongly agree that they have proposed creative solutions or viewpoints in their projects, a proportion significantly higher than other options, indicating that students actively exercise innovative thinking and are willing to try new solutions in workshops. Additionally, over half (50%) of students believe they perform very well in solving problems independently or through collaboration, further demonstrating their outstanding problem-solving abilities and teamwork spirit when facing challenges.

However, questionnaire data has also highlighted some challenges in the areas of project planning and organization, time management, and interdisciplinary integration. Although some students perform well in these areas, many others

express difficulties. For example, in project planning and organization, while 38.89% of students rate their performance as excellent, a considerable proportion (61.11%) believe their project plans need improvement or they have deficiencies in organizing and managing project tasks. In time management, despite some students indicating they can arrange time reasonably (38.89%) and another 44.44% giving positive evaluations, some students may still impact project progress due to improper time management. In interdisciplinary integration, although 44.44% of students rate their performance as excellent, some students face challenges in integrating knowledge across different disciplines and providing interdisciplinary solutions, which may be related to their disciplinary backgrounds, knowledge accumulation, and opportunities for interdisciplinary exchanges.

In response to these challenges, future workshops should develop targeted improvement strategies. For example, in the area of project planning and organization, more project planning and management tools can be provided to assist students in crafting more detailed and feasible project plans. In terms of time management, instruction on time management skills should be enhanced to guide students in allocating their time appropriately, ensuring the timely completion of project milestones. As for interdisciplinary integration, activities such as interdisciplinary lectures and seminars can be organized to facilitate exchanges and collaboration among different disciplines, thereby enhancing students' interdisciplinary integration capabilities.

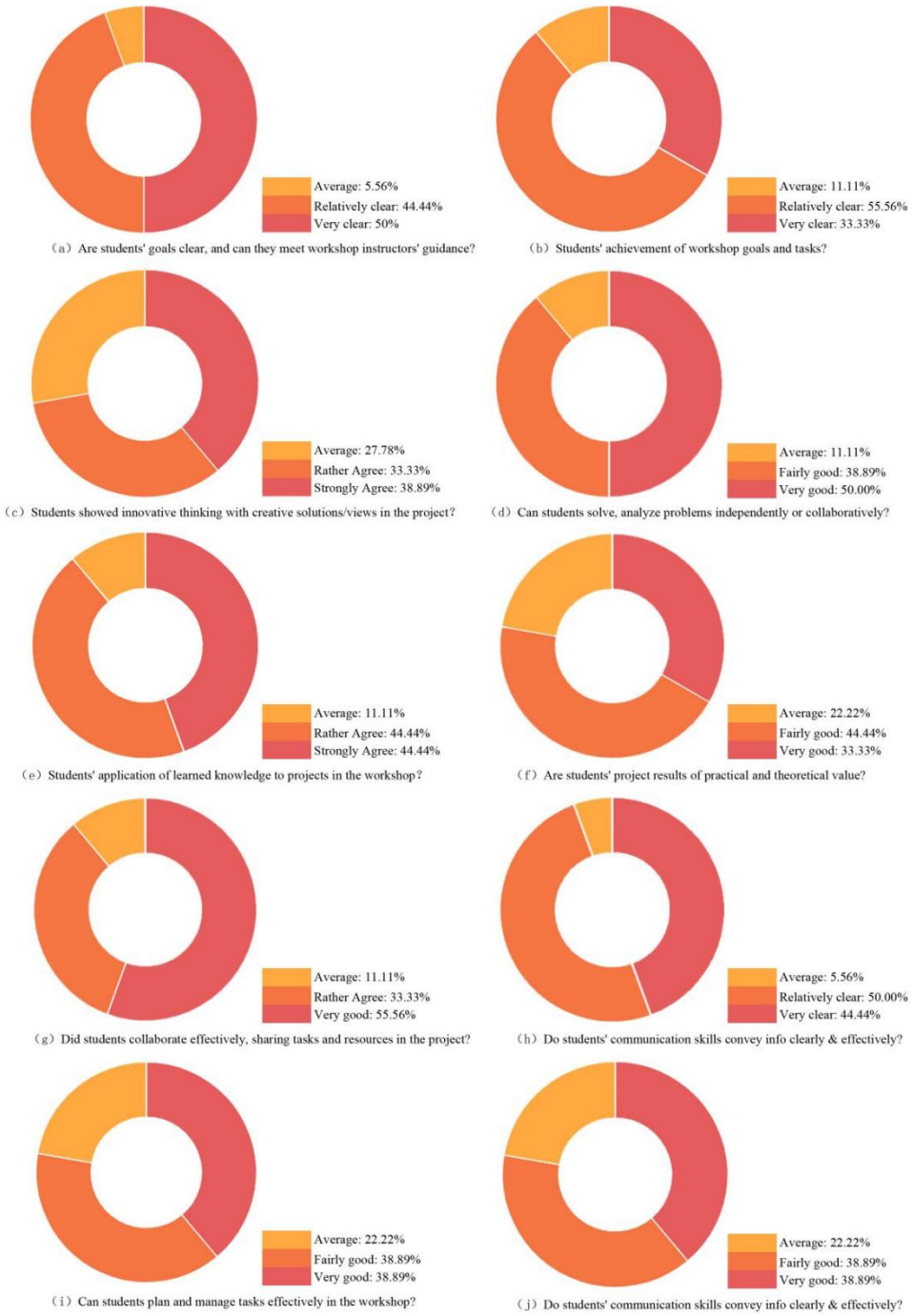


**Figure 4** Analysis of Evaluation Results for the Teaching Reform Process

## 4.2 Demonstration of Teaching Reform Effectiveness

### *4.2.1 Dual Optimization of Teaching Quality and Learning Ecology*

Firstly, the teaching reform has significantly enhanced students' comprehensive abilities. Through the studio project-based teaching model, students are placed in real project environments and tasked with actual design responsibilities. This not only exercises their practical abilities but also cultivates innovative thinking and problem-solving skills. In projects, students learn how to communicate with clients, coordinate team members, handle unexpected issues, and integrate knowledge and skills from different disciplines, thereby enhancing their interdisciplinary integration capabilities. The improvement of these comprehensive abilities lays a solid foundation for students' future careers. Secondly, the teaching reform has improved teaching quality and student satisfaction with learning. In the studio project-based teaching model, teachers can more intuitively understand students' learning situations and progress levels, providing them with more targeted guidance and assistance. Meanwhile, students can feel their growth and progress during the project participation process, thereby increasing their learning enthusiasm and satisfaction. This teaching model not only promotes interaction and communication between teachers and students but also enhances students' learning motivation and self-confidence.

### *4.2.2 Enhancement of Interdisciplinary Integration Capabilities*

The studio project-based teaching model encourages students to exercise innovative thinking and propose novel design concepts and solutions. During project execution, students face various challenges and constraints, such as budget limitations and site restrictions. These challenges prompt students to constantly think, explore, and innovate, thereby enhancing their innovative thinking and problem-solving abilities. Meanwhile, the landscape architecture major involves multiple disciplinary fields, such as architecture, horticulture, ecology, etc. In the studio project-based teaching model, students need to collaborate with team members from different disciplinary backgrounds to jointly complete project tasks. This interdisciplinary collaboration mode prompts students to learn how to integrate knowledge and skills from different disciplines, thereby enhancing their interdisciplinary integration capabilities. In projects, students not only deepen their understanding of the landscape architecture major but also broaden their knowledge horizons.

### *4.2.3 Successful Transformation and Application of Studio Project-Based Teaching*

The successful implementation of the studio project-based teaching model in the landscape architecture major is not only reflected in the improvement of students' practical skills and the optimization of teaching quality but also in its successful transformation of teaching projects into practical applications, while simultaneously promoting in-depth research by teachers and frequent outstanding performance in student design competitions. On the one hand, studio project-based teaching is closely integrated with industry demands, encouraging students to participate in the design and implementation of real projects. These projects not only provide students with valuable practical experience but also submit their design outcomes to design competitions (Figure 5). On the other hand, studio project-based teaching also promotes the in-depth development of teachers' research topics. By guiding students to participate in projects, teachers continuously accumulate practical experience and, combined with teaching needs, carry out a series of highly targeted and practical research topics. These research topics not only enrich teaching content, improve teaching quality, but also provide a research foundation for subsequent landscape architecture teaching reforms.

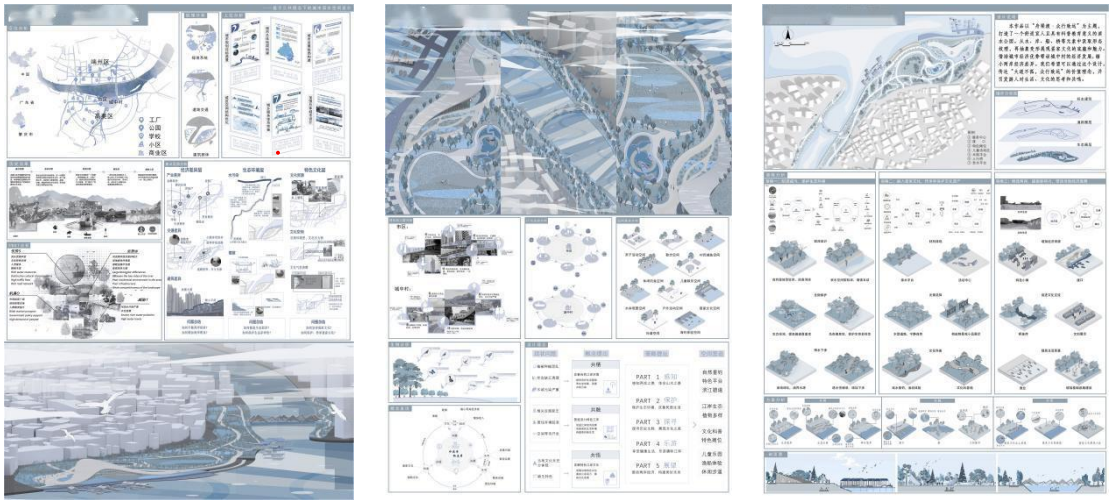

**Figure 5** Exhibition of Student Achievements

## 6 SUMMARY AND DISCUSSION

This paper focuses on the research of teaching reform in the landscape architecture major from the perspective of studio-based project application. Taking the landscape architecture major at Guangdong Technology College as an example, it delves into the teaching reform practices within the industry-academia-research ternary system. By introducing enterprise projects and cooperative mentors from both the college and enterprises, a studio-based project model is established, which effectively enhances students' comprehensive abilities, optimizes teaching quality and learning ecology, and successfully achieves the transformation and application of teaching projects. Although the studio-based project teaching model has achieved certain promotional value and application prospects in the reform of the landscape architecture major, there are still areas for improvement, and targeted improvement strategies have been formulated. For example, in terms of project planning and organization, more project planning and management tools can be provided to assist students in developing more detailed and feasible project plans. In terms of time management, the teaching of time management skills can be intensified to guide students in making effective time arrangements and ensuring the completion of project milestones as scheduled. In terms of interdisciplinary integration, interdisciplinary lectures, seminars, and other activities can be organized to promote communication and cooperation among different disciplines and enhance students' interdisciplinary integration abilities. Furthermore, in the ongoing reform process, it is imperative to further deepen industry-academia-research cooperation, optimize teaching content and methods, and cultivate more landscape architecture professionals with innovative and practical abilities to meet the demands of modern society. Additionally, this study offers valuable references and insights for the teaching reform of other majors.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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# DISCUSSION ON THE PROBLEMS AND SOLUTIONS OF CONSTRUCTION PROGRESS MANAGEMENT

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**Abstract:** In today's Chinese market, the scale of construction projects is expanding, construction enterprises are growing, and construction enterprises are facing increasingly fierce market competition in the construction process. In this market environment, if enterprises want to maintain their advantages in the market, they must improve their own management level. Only by completing the required construction schedule on time and with high quality can construction enterprises occupy a dominant position in the market competition. Whether the construction progress of the construction project can be completed on schedule directly reflects the project management level of the construction enterprise. Through the investigation of construction progress management, there are still major problems such as unreasonable construction schedule, inadequate construction organization and implementation, imperfect management of construction equipment, insufficient guarantee of construction funds, and low technical ability of construction personnel.

**Keywords:** Construction engineering; Construction progress; Schedule management; Project management

## 1 RESEARCH BACKGROUND AND SIGNIFICANCE

### 1.1 Research Background

In recent years, due to the increasing number and scale of construction projects, the progress control of construction has been paid more and more attention by construction enterprises, and many construction progress theories and methods have been widely recognized and applied. But there are still some enterprises in the project construction only according to the perennial construction experience to control the construction progress, no scientific evaluation of construction progress, often appear, resulting in the best economic benefits, and part of the enterprise of the construction schedule management is often not comprehensive, only strictly control the construction period, unable to effective control of resources, funds, which caused the period and cost cannot perfect fusion in, resulting in the construction project cannot achieve the ideal benefit.

### 1.2 Study Significance

In the fierce market competition, if the construction enterprises want to gain the leading position, they must take active measures to manage the project, focus on the construction schedule management, ensure that the quality meets the design standards, scientifically control the construction period, and reduce the project cost input to the minimum, so that the enterprise is far ahead in the industry[1]. In order to ensure that the success of the construction project can be completed, the construction enterprise should strengthen the control of the construction project, reduce the cost of the construction, under the premise of the overall benefit of the construction project. Only in the management of the construction progress is strictly controlled, in accordance with the schedule arrangement, so that the construction project can be carried out smoothly, to ensure the quality of the construction project, improve the efficiency of the construction project, to achieve the purpose of economic benefits and social benefits. Therefore, the construction enterprises must strictly abide by the engineering standards, efficiently complete the construction tasks within the specified time, ensure the quality and efficiency of the project, actively carry out the project progress management work, optimize the management mode, coordinate every link in the construction process, complete the project construction on time, and realize the optimal development of the project construction[2].

## 2 RELEVANT KNOWLEDGE OF BUILDING CONSTRUCTION PROGRESS MANAGEMENT

### 2.1 Meaning of Construction Schedule Management

The total progress of a construction project is the progress objectives determined in the project definition stage, and the main task of construction progress management is to control these objectives in the implementation stage.
Construction schedule management refers to the control and management in the process of project construction, According to the schedule requirements of the construction contract, According to the content, procedure, duration and connection mode of the project, Using scientific management methods to track, supervise and check the actual progress

of the project, And after a careful and detailed comparison, Find out the difference and differences between actual and planned, And evaluate and analyze the formation of differences and differences and make plans, For the plan to be implemented in the execution of the project, And regularly check the implementation of the project, And to analyze the implementation of the project plan, And analyze the effects of it, And to correct or modify it, Until completion and delivery.

### 2.2 Principles of Construction Schedule Management

Dynamic control principle: Construction projects are a complex and dynamic system, which is affected by a variety of internal and external factors, such as design changes, material supply, construction conditions, natural environment, policies and laws, etc., resulting in the progress of the project is difficult to predict and stabilize[3]. Therefore, when the construction progress is controlled, it is necessary to compare the actual progress with the planned progress in real time, so as to find the plan in time, and analyze and correct it, so as to ensure the normal progress of the construction.

Systemic principle: construction progress systematic principle, refers to the actual construction process, a certain project or a specific setting link in the project as the whole project or a part of it, through effective methods and systematic thinking to manage[4]. Construction work is through the project manager assigned to the head of each professional, each professional head to lead staff to complete the construction work, and in the whole construction process, dominated by the project manager, collaboration between other professional work, so the construction work is a kind of organized system engineering. The control of the construction progress should also be carried out systematically according to the systematic vertical transmission of information.

Information feedback principle: Information feedback is an important way in the progress control process of construction projects. In the event of any deviation in the construction schedule, the construction enterprise should make corrections to the original construction schedule, which should be based on accurate progress deviation information. These information also needs to be conveyed to the decision makers timely, effectively and accurately through specific procedures and channels. On this basis, there should be rich managers to summarize, analyze and summarize these data, and then vertically convey them layer by layer. In the process of decision formation and implementation, managers should pay close attention to the impact of correction actions, and provide timely information to decision makers to provide the basis for the next step of control.

Elastic principle: in the process of construction progress control, it is often affected by various factors, which is inevitable. To ensure certain major milestones in the construction plan.

## 3 MAIN PROBLEMS EXISTING IN THE CONSTRUCTION SCHEDULE MANAGEMENT

### 3.1 Unreasonable Construction Schedule

In the process of construction, due to the many and complicated construction steps, the situation encountered in the construction process is more complicated, and the construction progress management and the formulation of the progress plan are closely related. The smooth progress of building construction must have a set of scientific progress planning as its guidance and support. Improper construction schedule will cause the project delay, increase the project cost, and reduce the quality of the project. Especially in major projects and complex projects, due to the improper arrangement of the schedule, it will not only cause engineering risks, but also cause engineering quality, safety and other problems, which will cause great damage to the construction progress.

The unreasonable construction schedule is mainly reflected in the large difference between the construction schedule plan and the actual construction situation, which leads to the delay of the normal construction progress. The root cause of this problem is that, in the initial design stage, because of the large scale of the construction, and the uncertainty about the work, let the early construction and planning work appear more difficult, when many construction enterprises make the schedule, often associated with randomness and idealization, ignoring the limitations of the site construction, without fully considering the specific circumstances of the project, therefore, Inaccurate arrangement, The formulated construction schedule plan cannot provide a reference for the specific work, this is likely to hide the problems arising in the actual construction, thus the estimation of the overall amount of work, if an emergency occurs during the construction process, it is very difficult to develop an effective emergency rescue plan, in severe cases, it will stop work, slow down the construction progress, it will also cause the deviation between the progress management and the management plan, later will involve the construction project rework and repair work[5]. In addition, the focus of the construction schedule planning is insufficient. In the whole construction process, it involves many complicated aspects such as site survey, material and machinery supply, and construction implementation. The content of the construction schedule planning is too single or too complicated to efficiently track and control the construction process.

### 3.2 The Construction Organization and Implementation is not in Place

When the construction organization is not in place, it will inevitably directly lead to the construction progress delay, quality problems and engineering safety risks and other problems. Site layout in the process of construction is unreasonable is the key factor directly affecting the construction progress, first, the construction site area is limited, if the site organization arrangement is unreasonable, building materials without basis, mechanical equipment into not clear, in the need to approach material machinery, not appear in time, delay the next material machinery approach, will

inevitably affect the construction progress. The site logo is not clear, the distance between the living office area and the construction site is too close, and the control of dangerous goods is lax. Once safety problems occur and there is no clear safety indication area, it is not only a threat to personal safety, but also will cause irreversible consequences to the construction progress.

Second, construction organization and implementation is not in place, quality control aspects, In the construction, there are often the site personnel team did not carry out the construction in strict accordance with the construction instructions in the technical disclosure, often use their own years of experience to deal with the details, if the project department does not find out and deal with it in time, the supervisor fails to pass the inspection, many partial projects are reported and re-construction is a serious delay to the overall construction progress; Time-node aspect, when the site personnel team carries out the partial project in time order, if the construction is not strictly according to the schedule, the delay time of each sub-project is accumulated, will cause the delay of the overall construction time node. On the contrary, some construction enterprises in order to blindly pursue construction progress, violate the acceptance process, the previous process without acceptance on the next process, before a partial project problems because has started the next partial project lead to rework, supervisor cannot complete the acceptance, seriously hinder the construction progress, even the project rot.

### 3.3 Imperfect Management of Construction Equipment

With the rapid expansion of the scope of mechanical construction, there are still many management problems in the construction of engineering equipment. Some construction enterprises do not fully realize the importance of construction equipment maintenance work, the construction equipment management work problems, the main reason is that the management system of construction equipment is not sound, and its implementation is not enough. Some construction enterprises only pay attention to the use of equipment, do not pay attention to its maintenance, only pay attention to short-term profits, ignore the long-term operation, resulting in a large number of construction machinery in a long time overload operation, which will aggravate the wear and aging of machinery and equipment, reduce its working life. When the equipment cannot be used, the enterprise needs to pay more energy and financial resources to carry out maintenance, which increases the maintenance cost and delays the construction period, which will cause chaos in the management of construction equipment management, and the completion of the project schedule causes a great impact.

In addition, although some enterprises have established a corresponding complete maintenance system, but it has not been effectively implemented, and the management of construction equipment is weak. In the case of large construction workload, the enterprise existing construction equipment is often difficult to meet the requirements of the construction, and the construction workload is small or no work, these equipment will be completely idle, led to a huge waste of resources, and equipment aging problem will appear, thus limiting the construction process of the enterprise.

### 3.4 Insufficient Guarantee of Construction Funds

The normal construction of construction requires a large amount of funds, because the construction project itself has the characteristics of long cycle, large demand for funds, long cycle of capital use and so on, which makes it difficult for construction enterprises to avoid the situation of insufficient capital guarantee. Inadequate construction fund guarantee will lead to the delay of project progress, project quality decline, construction team members lax and other problems. Once the capital chain is broken in the construction process, the project will lead to the shutdown. If the enterprise capital investment is insufficient, it is difficult to guarantee the cost in the construction process, which will inevitably have a serious impact on the overall project progress.

Cause construction funds guarantee there are many reasons, the first construction enterprise is responsible for the capital staff is not professional financial personnel, they do not have enough professional knowledge, and their information degree is not high, so when they use modern management technology and equipment, cant be the assets management system and equipment function fully use. Second non-professional financial personnel quality level is not enough, not for fixed capital management, or the financial management is not serious, not responsible for it, this will cause problems in financial accounts, will produce financial distortion, this increases the financial risk, but also reduce the accuracy and accuracy of financial information, further let enterprises to reasonable allocation of liquidity, will eventually cause the circulation of funds.

In addition, the construction enterprises own financial management system implementation is not sound. First of all, some construction enterprises lack the corresponding financial supervision departments, and also lack of matching financial supervision mechanism. Second construction enterprise capital experience is not scientific, problems in the use of funds, unreasonable use of capital and non-standard management, let enterprises cant accurately understand their operating status, which has a certain influence on the decision, also let the company financial staff cannot effectively effective accounting of capital, let the enterprise in a state of capital chain tension. The capital flow of the construction project is blocked, which affects the time period of purchasing materials and components, and slows down the progress of the project.

### 3.5 Low Technical Ability of the Construction Personnel

All the technical operation and organization cooperation in the construction process need the participation of people, and the unreasonable allocation of construction personnel will undoubtedly have a direct impact on the construction progress[6]. People are an important part of the project construction, the low level of construction technology is often caused by the lack of professional knowledge, lack of practical experience, lack of training and other factors, therefore, the site staff will appear technical performance is not strong, operation error, the construction requirements are not clear and other problems. The main reason for the above problems is that the technical standards of the construction enterprise project department are too lax on the inspection, resulting in ineffective supervision work, resulting in a large number of illegal operations, and then reduce the benefits of the project construction. If there are problems such as insufficient workers, mismatched skills, or inadequate training, it will lead to a lag in the project[7].

At present, the technical level of construction workers in construction enterprises is relatively poor, which is embodied as follows: first, the technical level of management personnel is not high, and many project managers do not have the corresponding business skills, nor the corresponding production technology management skills. In the process of project implementation, there is a big gap between the composition of technical personnel and the actual situation of the project, and it is difficult to effectively control the implementation process of the project. Not enough understanding of the true process of the project. In addition, the overall planning of the project also lacks the overall consideration of the overall planning due to the lack of its technical level. In the construction of the project, there are often some unexpected situations. If these unexpected situations are not solved timely and efficiently, it will cause the delay of the project period. In addition, because most of the construction workers are mainly heavy physical work, without special skills training, so they do not master the appropriate construction work skills, some will also appear the phenomenon of illegal work. In the actual construction process, the operation of the machine mainly depends on the subjective feelings of the operator, resulting in more time-consuming operation process, and a certain impact on the quality of partial projects, often rework, which seriously restricts the construction process of the project.

## 4 SOLUTIONS TO PROBLEMS IN CONSTRUCTION SCHEDULE MANAGEMENT

### 4.1 Improve the Construction Schedule

The preparation of construction plan is an important part of the project schedule management. On the basis of the construction plan, improve the construction schedule, reasonably arrange the supply of resources, save the construction cost and ensure the smooth construction. To give enough attention to all possible factors, to exclude, to make the construction schedule become more perfect, you must to each stage, each step of the detailed analysis, resources in each link of reasonable configuration, and the optimal construction structure adjustment, but also strengthen the monitoring and tracking, build a set of effective communication and coordination mechanism, so as to ensure that the construction schedule can get effective execution and success.

In the process of construction progress plan, according to the actual construction characteristics, different construction conditions for the specific analysis, before construction, construction enterprises must according to the relevant requirements, provide a detailed construction plan, and then by the supervision personnel review the construction plan, to ensure the feasibility and safety of the construction scheme, ensure the construction quality of the project, to meet the basic requirements of the project management. In addition, at the time of construction scheme review, the auditor should attach importance to the project construction target review, will each item and the connection between the overall project clear, in order to realize the fine management, make the project progress conform to the requirements of the construction contract, and promote the progress of the project management. At the same time, the feasibility analysis of each construction step is also carried out, so as to make a more scientific plan in line with the original project schedule. After the start of the construction, schedule management personnel to improve the project guarantee measures, collect the actual progress of the progress report or routine progress report to complete data check and collect, to ensure the correctness of the data, progress management personnel should regularly to the site, understand the specific progress of the project. Construction personnel should carry out the construction in strict accordance with the system and do it.The progress of the project should be strictly tracked and regularly tracked. Once the progress delay is found, the problems should be reported in the first time and solved to ensure the smooth progress of the project.

### 4.2 Optimize the Construction Organization and Implementation

Construction enterprises in the construction organization and implementation, to be in strict accordance with the construction organization design. In the aspect of site management, the building materials and materials, based on the overall layout plan, the building materials and materials should be scientifically stored, but also be marked, and the timely storage and transportation of construction and household garbage.

During the site construction implementation, relevant management personnel should strictly control the quality of the construction site, clarify the project construction condition, record the detailed information of the construction link of each section, use this information to provide a strong basis for the acceptance of partial projects, benefit to the overall management of the construction project, enhance the efficiency of construction project management, and then improve the construction progress; in addition, the management personnel control of the construction time node should also be accurate, conduct each sub-project as per the schedule as possible, in the face of the delay time of the field personnel team rectification punishment, take measures of rewards and punishments accordingly, according to the terms of the labor contract, to commend the on-site personnel team who have completed the work content in advance, fully tap the

potential of the site personnel team, while ensuring the smooth construction progress, it can also promote the progress of the construction project. To optimize the implementation of construction organization and implementation, it is necessary to establish a scientific management system and work system from the aspects of construction equipment, material management, safety management, communication and supervision, and ensure the efficiency and quality of construction organization and implementation to ensure the smooth construction progress.

### 4.3 Strengthen the Management of Construction Equipment

Construction equipment plays an important role in the construction. Strengthening its management can effectively improve the construction progress, reduce the construction cost, and help to improve the quality of the project and ensure the construction safety. Strengthening the management of construction equipment is an important measure to ensure the construction progress and quality. It is necessary to strengthen the management from the management organization, standard system, maintenance, storage system and safety management, to ensure the safe and effective use of construction equipment, which has a great impact on the smooth progress of the construction progress.

During the project initiation phase, detailed demand analysis and market research are carried out to determine the specifications, quantities and delivery times of the required equipment[8]. Furthermore, according to the construction scale and demand, set up special equipment management department, set up the specialist is responsible for the equipment storage, use and maintenance, and apply to information technology, build and perfect a complete system of equipment maintenance management system, standardize the file processing process, so as to improve the efficiency of maintenance and management. At the same time, the establishment of equipment files and maintenance records, detailed understanding of the use and use cycle of equipment, for different types, different types of machinery, establish its operation parameters files. To build a perfect mechanical operation post responsibility system, the establishment of full-time mechanical management departments, in the construction rules and regulations of the responsibilities and obligations of each staff. Formulate the equipment use and operation specifications, require the construction personnel to use the equipment safely under the condition of ensuring its normal operation, and increase the awareness of the use and maintenance of the construction personnel. The mechanical equipment should be inspected to ensure that the mechanical equipment can meet the construction requirements of the bid section, conduct regular inspection and maintenance of the mechanical equipment and make inspection records, and replace the equipment that does not meet the site requirements in time[9].

### 4.4 Guarantee of Construction Funds

At present, there are often capital problems in part of the construction, and the capital chain is broken during the construction, which leads to it difficult to continue the construction of the project, which seriously affects the construction progress. Therefore, the construction unit should strengthen the control of funds to ensure the sufficient funds of the project[10]. Construction enterprises should increase the training of employees, improve the professional level and quality of financial management personnel, so that financial personnel can have a more comprehensive understanding of the relevant knowledge and skills of financial management, so that they have independent decision-making and risk control ability. At the same time, we should strengthen the management and operation of the assets of enterprises. To ensure that the selected financial personnel have a certain risk control awareness and management ability, to carry out careful statistics of financial information, to work carefully, to ensure the accuracy of financial statements and data information, to be able to effectively prevent financial crisis, which is of great help to the control of financial risks. Managers should strictly control and manage the funds at any time, control the accurate financial information, and be able to ensure that there are sufficient funds to buy the required materials and equipment in the repayment process, so as to make the flow of funds more active.

In addition, before the project is approved, the construction enterprise should, according to the actual situation of the project construction, plan the specific budget and fund source of the project, clarify the fund demand and fund raising plan in the project construction, and formulate a set of reasonable fund use plan. Establish a sound internal management system, strictly manage the flow of financial funds, strengthen the management of financial funds, and implement the risk control mechanism and internal management system in place. In this way, financial personnel can be more clearly aware of the significance of financial risk management, so as to better grasp the countermeasures of financial risk management. When carrying out financial work, we must be in accordance with the requirements of internal management, a careful analysis of the needs of funds, and combined with the realistic conditions of a reasonable flow of funds, the use of financial funds is strictly controlled. In addition, it is necessary to ensure that sufficient funds can be repaid on time, effectively improve the efficiency of the use of capital, so that it can carry out scientific working capital circulation, so as to effectively control financial risks. Managers should always abide by the provisions of the internal management system, and manage and supervise the flow and circulation of financial funds, so as to avoid financial risks and prevent misappropriation of funds or lax management. At the same time, strengthen the management of the assets and capital of the enterprise shall ensure the internal control of the enterprise and prevent the financial style of the enterprise.

### 4.5 Improve the Technical Ability of the Personnel

The main body of the construction is the construction personnel, and the technical ability level of the construction personnel directly affects the construction progress of the whole project. Therefore, it is particularly important to do a good job in personnel assessment management, strengthen the control of access, performance and arrival, and improve the mastery of the number of construction personnel and the amount of work by project management personnel to improve the level of progress management[11]. These training can be taught by internal engineers and technicians, or by external professional institutions. To regularly for construction management and site construction personnel management and professional skills training, to strictly abide by the approach clarification, before shift education system, using simulation work, let the construction personnel in the actual work can better master their own technology, so as to improve their work efficiency, strengthen their technical accumulation and the ability to deal with job changes, so that the construction personnel can use their construction equipment at the scene, and can be skilled operation, as far as possible for the construction personnel to their mechanical operation to zero deviation, make their work better implement, make the construction quality get better.

In addition, in the construction personnel on-the-job training, should also implement strict on-the-job evaluation system for them, and regular inspection of them, and their comparison and feedback, supervise the staff work progress and skills, and give real-time feedback and improvement Suggestions, motivate employees, ensure that employees have high work enthusiasm and quality consciousness, to ensure that the construction of the enterprise construction personnel with high quality, ensure the construction progress, no delay.

## 5 CONCLUSION

At present, under the background of the rapid development of national economic construction, progress management plays a very important role in construction, It can not only improve the efficiency of project management, but also better control the construction quality and safety, but also reduce the incidence of construction safety accidents. In the process of construction, the construction unit must conduct a comprehensive analysis and study of the various influencing factors of the construction project progress. According to the problems in the construction progress management, take corresponding measures to actively control the construction progress. In the whole project, all the participants take active actions, make full use of strengths and circumvent weaknesses, and work together. Under the joint efforts of various majors and each link, can we formulate a scientific construction schedule plan and build a reasonable control system, to ensure that the project progress can meet the provisions of the contract. Only by effectively controlling the construction progress, can the construction enterprises achieve stable development in the construction field, so as to promote the sustainable development of the construction market.

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## COMPETING INTERESTS

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