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MOLECULAR DYNAMICS SIMULATION OF THE STRUCTURE AND PROPERTIES OF GEOPOLYMER GEL

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ABSTRACT

Fly ash captured by power plant can be mechanically grounded, activated, and then stimulated with strong alkali to produce a chemical reaction called geopolymer. Geopolymer gel is a material with a 3D network structure, which is widely used in architecture and material science. This research aims to study the structure and properties of geopolymer gel through modeling and molecular dynamics simulation. Firstly, this paper describes the molecular structure of geopolymer gel in detail using advanced modeling techniques, including the Compass force field and molecular dynamics calculation. The molecular dynamics method studied six geopolymer gel systems with different structures, and their elastic modulus, radial distribution function, and XRD patterns were deeply discussed. The results show that the elastic modulus of the geopolymer gel simulated in this study is 22.9~39.1 GPa, close to the experimental result of 47.2 GPa. The first peak positions of H-O bond, Si-O bond, Al-O bond, and O-O bond in the radial distribution function is approximately 0.097, 0.161, 0.177, and 0.263 nm, respectively, which are consistent with the experimental values. In the XRD spectrum, the dispersion peaks are distributed within the 2θ range of 10° to 40° , consistent with the distribution characteristics of the dispersion peaks observed in the experiment. The values obtained from molecular dynamics simulations align closely with those derived from experimental data, which not only verifies the validity of the structural model built but also provides a possibility for further in-depth research on the geopolymer gel system.

Keywords:

Fly ash geopolymer, Gel structure model, Molecular dynamics, Molecular structure characteristics

INTRODUCTION

With the acceleration of global industrialization and urbanization, the demand for building materials has sharply increased, which poses enormous pressure on the exploitation of natural resources and environmental protection. Therefore, the field of building materials science is undergoing unprecedented changes aimed at developing more environmentally friendly, efficient, and sustainable new materials. In this context, geopolymer materials, as a type of green building material, have gradually attracted widespread attention from academia and industry due to their wide range of raw material sources, simple preparation processes, and excellent performance. Geopolymer materials are usually made from industrial waste (such as fly ash, slag, etc.) through specific processes, which not only realize the resource utilization of waste but also significantly reduce energy consumption and carbon emissions in the production process of building materials (Vishnuram et al., 2023; Zhao et al., 2024). However, despite the enormous potential of geopolymer materials in the field of sustainable construction, there are still many challenges and unknowns in terms of their microstructure, performance control mechanisms, and performance in practical applications (Duan et al., 2024; Rashad et al., 2024). Therefore, in-depth research on the relationship between the composition, structure, and properties of geopolymer materials, and exploring new methods for optimizing and modifying their properties, is of great significance for promoting the progress of materials science and the development of sustainable architecture.

Fly ash geopolymer cementitious material refers to a new type of building structural material that is an inorganic non-metallic material featuring a spatial network structure generated by the polymerization reaction of aluminum silicate minerals with volcanic ash activity or potential cementitious activity and alkaline compounds (Sasi Rekha & Sumathy, 2022). Geopolymer gel, characterized by its

unique inorganic polymer structure, has become an important class of materials, with a variety of applications from architecture to environmental restoration (Alsaif et al., 2022). These gels are synthesized by alkaline activation of aluminosilicate precursors and are expected to become sustainable substitutes for traditional cement-based materials. Although the performance issues of fly ash geopolymers have received widespread attention, traditional research methods mostly focus on macroscopic performance testing and evaluation, such as physical and mechanical properties, durability, etc. (Rashad et al., 2024). Although these methods provide valuable information, they have limitations in revealing deep-seated mechanisms such as the microstructure evolution and intermolecular interactions of fly ash. Geopolymer gel is the main reaction product and cementation phase of fly ash-based polymer materials. Its microstructure and performance are the basic units that determine the service performance of fly ash-based polymer materials (Guo et al., 2024; J. Li, Liu, et al., 2024; Y. Luo, Klima, et al., 2022). However, the structure and properties of geopolymer gel at the molecular scale have not yet been clarified (H. Wang et al., 2021). Therefore, to gain a deeper understanding of the properties and behaviors of fly ash and its geopolymer materials, more sophisticated research methods need to be introduced, and molecular dynamics (MD) simulation is such a powerful tool that can simulate the dynamic behavior of materials at the molecular scale, providing microscopic insights for explaining macroscopic properties. As a widely used computational method, molecular dynamics (MD) simulation can establish correlations between microscopic and macroscopic quantities or measurable properties. The motivation for this research is that there is a gap in our understanding of the structure of geopolymer gel at the molecular scale. MD simulation is a powerful computing tool, that provides an opportunity for an in-depth study of the complex details of the formation and behavior of geopolymer gel and provides a molecular-level perspective to supplement experimental observations (L. Li et al., 2023).

To fully understand the fly ash geopolymer gel, this study attempts to bridge the gap between macro-observation and molecular scale phenomena. By combining advanced modeling technology and MD simulation, this study aims to reveal the fine structure of geopolymer gel and the complexity of its molecular structure and mechanical properties. The main contribution of this study is to build the NASH molecular structure model of 6 fly ash geopolymer gel with different calcium silicon ratios and characterize the mechanical properties and physical properties at the molecular structure level. The molecular dynamics simulation method was used to optimize the simulation process and verify the accuracy of the model, providing a new approach for the research of geopolymer materials. The accuracy of the NASH model was verified by comparing existing literature, revealing the model characteristics of different calcium silicon ratios and their impact on mechanical properties. The research results have broad application potential in the fields of building materials, environmental protection, and resource recycling, which can help improve material performance and reduce costs.

REVIEW OF MOLECULAR STRUCTURE RESEARCH ON FLY ASH GEOPOLYMERS

FORMATION MECHANISM OF FLY ASH GEOPOLYMER GEL

The intrinsic complexity of fly ash geopolymer gel stems from the complex interaction of chemical reactions in its formation process. The formation mechanism of geopolymer gel at nanometer scale is a complex and precise process, involving multi-step physical and chemical interactions. This process is usually realized by alkali excitation reaction, and its core steps include the dissolution of raw materials, the formation of polymers, and the development of three-dimensional gel networks (S. Chen et al., 2022; J. Li, Ma, et al., 2024).

The starting point of forming geopolymer gel is the dissolution of fly ash. Alkaline activators and silicate components in fly ash dissolve in water, forming solutions containing silicon, aluminum, oxygen, and alkaline substances. In alkaline environments, the tetrahedra and hexahedra of silicon and aluminum in silicates begin to undergo hydrolysis and polymerization reactions. During this process,

hydroxide ions and water molecules participate, promoting the rearrangement of silicon and aluminum atoms to form polymers (Yuan et al., 2021). The formation of polymer is a key step in the formation of geopolymer gel, which is composed of chain or ring polymers of silicon oxide tetrahedron and aluminum oxide hexahedron. As the polymers form, they gradually connect to form a 3D network structure (J. Li et al., 2022; H. Y. Zhang et al., 2021). The stability and strength of this network depend on the shape, size, and interconnectivity of the polymers. At the same time, water molecules are also incorporated into the network structure in this process, increasing the water content of the gel. Water molecules combine with silicon-oxygen and aluminum oxygen bonds in the gel network to form hydrogen bonds and hydration bonds, further improving the stability of the gel. As the reaction continues, the geopolymer gel gradually becomes harder and more stable from the initial fluid or colloidal state. On a nanometer scale, the microstructure of gel is affected by many factors, including the nature of raw materials, the type and concentration of activator, reaction temperature, etc. The formation mechanism of geopolymer gel at the nanometer scale is a process of dynamic equilibrium, involving the synergism of various physical and chemical reactions (S. Chen et al., 2022; Wu et al., 2024). The microstructure directly affects the gel's pore structure and mechanical properties (Ge et al., 2024).

MOLECULAR STRUCTURE OF GEOPOLYMER GEL

The geopolymer obtained through the polymerization reaction is composed of a 3D network structure composed of $[\text{SiO}_4]^{4-}$ and $[\text{AlO}_4]^{5-}$ tetrahedra bonded alternately by bridging oxygen. According to Davidovits' (2020) research, the structural monomer products generated by polymerization reactions in geopolymers have three forms: polysialate (PS), Si: Al=1:1; polysialatesiloxo (PSS), Si: Al=2:1; polysialatedisiloxo (PSDS), Si: Al=3:1. Geopolymer gel network structure is mainly formed by condensation and connection among PS, PSS, and PSDS. The condensation process of Si-O tetrahedron and Al-O tetrahedron in the polymerization process differs from cement materials' hydration process. Water is only used as a reaction medium in the geopolymer reaction, and most of the water will be removed to become solid gel in the final system of the reaction (Frasson & Rocha, 2023; Liang et al., 2023). Majidi (2009) research believes that both Si and Al elements in the geopolymer gel structure exist in the form of IV coordination, in which the $[\text{AlO}_4]^{5-}$ tetrahedron needs to rely on the cations (Na^+ , Ca^{2+} , etc.) in the structural pores to balance the overall electronegativity of the structure. The research of geopolymer gel generally involves the synthesis of calcium aluminosilicate hydrate (CASH) and sodium aluminosilicate hydrate (NASH) in the laboratory. The mineral composition and microstructure of the synthesized gel are studied using XRD, SEM/EDX, and HREM, and then the macro performance of the geopolymer is predicted (Walkley et al., 2021; Y. Wang et al., 2022, 2023; Yan et al., 2023).

MOLECULAR STRUCTURE OF FLY ASH GEOPOLYMER GEL

Existing studies have proved that the reaction products of geopolymer gel are mainly an amorphous structure formed by silicon tetrahedron and aluminum tetrahedron structure. According to the different calcium content, they can be divided into high-calcium and low-calcium systems. The hydration product of a high calcium system is generally CASH gel, and the hydration product of a low calcium system is generally NASH gel (Y. Wang et al., 2023).

On the research of NASH gel, Y. Chen et al. (2022) showed that in geopolymer, Si mainly exists in the form of SiQ_4 (2Al) and SiQ_4 (4Al), and Al exists in the form of AlQ_4 (4Si). Guan et al. (2022) successfully constructed a geopolymer gel model with 7 different Si/Al ratio groups as basic units and simulated the geological polymerization process through the condensation reaction between hydroxyl groups to generate water and form an aluminosilicate network.

In the research of CASH gel, Kalousek (1957) proposed for the first time that Al [4] (four coordinated Al atoms) can replace Si on the Si-O chain of the Tobermorite structure to form an Al-doped Tobermorite. Faucon et al. (1999) prepared CASH gel with $\text{Ca/Si}=0.66\sim 1.7$, $\text{Al/Si}=0.1$, and 0.3 by

hydrothermal synthesis. The substitution position and coordination distribution of Al in CASH gel were analyzed by NMR. Scholars have pointed out that Al can exist in 3 types of coordination: Al [4], Al [5], and Al [6]. Al [4] exists on the Si-O chain to replace the Si-O tetrahedra, which can increase the degree of polymerization of the Si-O tetrahedra. The negative charge generated by substitution is balanced by hydrogen atoms or alkali metal ions.

SELECTION OF SIMULATION TECHNOLOGY AND MODELING METHOD FOR GEOPOLYMER GEL

Quantum mechanical calculation and MD simulation have been increasingly used to model the structure and behavior of geopolymer gel. These techniques enable researchers to simulate the evolution of gel structure over time and provide information on the formation of molecular bonds, spatial arrangement, and dynamic characteristics (Guan et al., 2022). Choosing appropriate modeling techniques is crucial for capturing the unique characteristics of geological polymer structures. Recently, the advancement of computational simulation techniques has enabled traditional descriptive models to be transformed into predictive models. The establishment of models can not only verify or explain the information obtained from experiments but also predict some properties of materials, such as mechanical properties and transport properties, from the perspective of atomic size (Y. Chen et al., 2022).

Abdolhosseini Qomi et al. (2012) used the first-principal method to simulate the doping of Al in CSH gel. The results show that Al can exist in the CASH gel in the form of Al [4], Al [5], and Al [6], where Al [4] exists in the silica chain to bridge the broken silica chain, increasing the degree of polymerization of the silica-alumina chain. Al [5] and Al [6] exist in the interlayer space to connect silicate chains on different main layers, forming the CASH 3D network structure. First principles are more inclined towards theoretical calculations, as almost all properties of molecules can be obtained through computation. However, the computational complexity is usually very large, and can only be calculated on large computer clusters, greatly limiting research application scenarios. Molecular dynamics relies on Newtonian mechanics to simulate the motion of molecular systems, requiring much lower computational power than first principles and can observe the dynamic evolution process of the system. Relatively speaking, the current application of molecular dynamics is more extensive and mature.

CONSTRUCTION AND APPLICATION OF GEOPOLYMER GEL MODEL BY MOLECULAR DYNAMICS METHOD

Bagheri et al. (2017) constructed a NASH model using Si-O-Al oligomers, sodium ions, and water molecules, tested its mechanical and structural properties, and compared the model with experimental results to demonstrate its rationality. The geopolymer model is constructed using oligomers, which are easy to operate and can yield reasonable results. Y. Chen et al. (2022) obtained the NASH gel model by polymerizing Si (OH)₄ and Al (OH)₃ monomers using a reaction field (ReaxFF). Molecular structural characteristics obtained through simulation, including bond length, bond angle, and X-ray diffraction pattern of the gel, align well with test results reported in the literature. Chitsaz & Tarighat (2020) considered different silicon aluminum ratios and conducted MD simulations using the NASH model of structural aluminum silicate molecule Q4 [4Al] Si with various charge balance modes. Tang et al. (2024) reacted oligomers to form a 3D network structure of NASH under the ReaxFF force field, and studied the changes and degradation mechanisms of NASH performance in corrosive environments. The ReaxFF force field has been widely used in silicon aluminum polymer systems, but its simulation calculation process requires more precise control, computational resources, and computation time. More suitable for characterizing the kinetic properties of different substance reaction interfaces. Hou et al. (2018, 2020) analyzed the structure of NASH in geopolymers and found that the structure of N-A-S glass is highly similar to that of NASH. They constructed a NASH molecular model using existing N-A-S glass models and inserted H₂O molecules. Due to the similarity in molecular structure between water glass and NASH,

Wang et al. (2020) randomly replaced Si atoms with Al atoms in the existing water glass molecular model and successfully constructed a NASH model. Zhang et al. (2023) used a similar method to construct a NASH model based on the sodium silicate molecular model, and conducted in-depth research on the adsorption behavior of cations at the NASH interface, analyzing the impact of Si/Al ratio, ion concentration, and ion type on this behavior. Because NASH gel is amorphous at room temperature and has low crystallinity, it is difficult to accurately measure and describe its structural morphology under the current experimental conditions, so the general silicate crystal system, space group, and its parameters are still different from the structure of NASH gel.

In summary, there are three main methods for researchers to construct NASH models: first, modifying the NASH molecular model using sodium silicate or NAS glass models with similar structures to NASH; second, combining oligomer molecular models to obtain NASH molecular models; third, using reactive force fields (ReaxFF) based on the second method to obtain NASH models with three-dimensional network structures. The relevant physical and mechanical properties of these three models are consistent with real experimental results. Considering the consumption of computer computing resources, this study uses the method of combining oligomer molecular models to obtain NASH molecular models.

Table 1: Previous research on Molecular Simulation of NASH Geopolymer gel

| Study | Platform | Model | Density (g/cm ³) | Si/Al | Potential | Ensemble | Research Target |
|---------------------------|------------------|--|---------------------------------|-------|-----------|----------|--|
| Bagheri et al.(2017) | Materials Studio | NASH oligomers | 2.00 | 1 | Dreiding | NPT | Gel Properties |
| Chitsaz & Tarighat (2020) | Materials Studio | NASH gel | 1.7 | 2 | COMPASS | NPT, NVT | Gel modulus |
| Guan et al. (2022) | LAMMPS | NASH gel | 1.92~2.05 | 1,2,3 | ReaxFF | NVT | Gel properties |
| Y. Chen et al.(2022) | LAMMPS | NASH glass | 2 | 1~4 | ReaxFF | NVT | Gel Properties |
| Tang et al.(2024) | LAMMPS | NASH gel | 2.05 | 3 | ReaxFF | NVT, NPT | Gel properties |
| Fang et al.,(2024) | LAMMPS | Si,Al,O ,Na atoms | 2.42 | 3 | ReaxFF | NVT | Gel properties |
| R. Wang et al.(2020) | Materials Studio | Na ₂ SiO ₅ glass | 2.69,2.94 | 1,2 | COMPASS | NPT, NVT | Gel Structure |
| W. Zhang et al.(2023) | LAMMPS | Na ₂ SiO ₅ glass | - | 1,2,3 | ClayFF | NVT | Gel properties |
| R. Wang et al.(2024) | LAMMPS | Na ₂ SiO ₅ glass | 2.18~2.23 | 3,4,5 | ClayFF | NVT | Gel properties |
| Hou et al.(2018) | LAMMPS | NAS glass | 2.59 | 3 | ReaxFF | NVT, NPT | Polymerization & gel properties |
| Hou et al.(2020) | LAMMPS | NAS glass | 2.41 | 3 | ClayFF | NVT | Ion immobilization Structure and mechanical properties |
| Z. Li et al.(2020) | LAMMPS | NAS glass | 2.57~2.74 | 1,2,3 | ReaxFF | NVT, NPT | Structure and mechanical properties |

MODELING OF GEOPOLYMER GEL STRUCTURE MODEL AND EVALUATION OF MECHANICAL PROPERTIES

BASIC UNIT STRUCTURE MODEL

Referring to the method proposed by Wang Q et al.(2020), they constructed the structural models of PSS type and PSDS type geopolymer gel in the molecular simulation software *Materials Studio* with Ca, Na, H₂O, Si₂AlO₁₀, and Si₃AlO₁₃ as the basic units. When building the geopolymer gel structure, the models of Na, Ca, H₂O, OH, Si₂AlO₁₀, and Si₃AlO₁₃ are clearly defined in the *Materials Visualizer* module and carried out geometric optimization in the *Forcite* module to ensure the accuracy and stability of the model. The specific forms of the optimized basic unit structure models are shown in Figure 1.

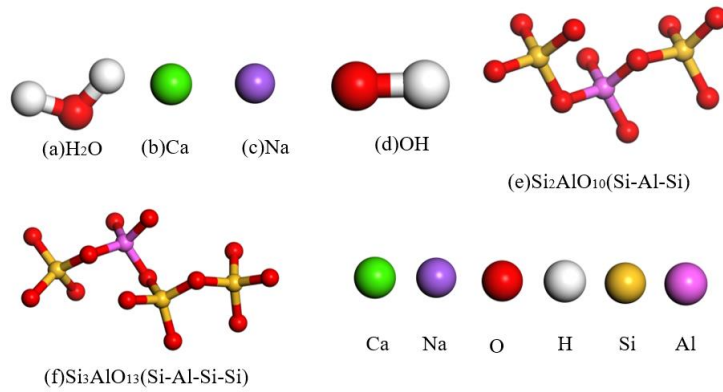


Figure 1: The basic unit of geopolymer gels

STRUCTURAL MODEL OF GEOPOLYMER GEL

Considering the influence of different Ca/Si ratios and Si/Al ratios on the mechanical properties of the model, the number of basic structural units when building the gel structure model is shown in Table 2. For the initial structure model of the gel that has been constructed, the *Focrcite* module is used for geometric optimization and MD simulation. First, the Geometry optimization in the *Focrcite* module is used, and the maximum number of optimization steps is 10000. The system is optimized in two steps (Steepest and Quasi-Newton methods). Afterward, *Energy* was used to minimize the energy of the system, and *Dynamics* was used for MD simulation. At a temperature of 298 K and a pressure of 0.001 GPa, the initial structure was equilibrated for 500 ps in the NPT ensemble with a time step of 1 fs, and then the structural system was further optimized for a duration of 500 ps in the NVT ensemble, to achieve a stable equilibrium state of the system molecules. Because the system simulated in this study is a mixed system composed of metal oxides and non-metal oxides, belonging to a generalized inorganic covalent bond system, the parameters obtained from ab initio calculations are reliable, and the COMPASS force field has the widest applicability in covalent bond simulation systems(Chitsaz & Tarighat, 2020). In this experiment, the *Compass* force field was chosen for all modeling and calculations. The *Universal* force field covers the universal force field of the entire periodic table, but the accuracy is average. This article will also compare the mechanical performance simulation results under the *Compass* force field and *Universal* force field. The final gel structure model after structural optimization and MD simulation is shown in Figure 2.

Table 2: Basic unit of geopolymer gel structure model

| NO. | Ca/Si | Si/Al | Na | Ca | Si ₂ AlO ₁₀ | Si ₃ AlO ₁₃ | H ₂ O | OH |
|--------|-------|-------|----|----|-----------------------------------|-----------------------------------|------------------|----|
| NASH-1 | 1:2 | 2:1 | 5 | 10 | 10 | 0 | 6 | 10 |
| NASH-2 | 1:3 | 2:1 | 10 | 10 | 15 | 0 | 7 | 10 |
| NASH-3 | 1:4 | 2:1 | 15 | 10 | 20 | 0 | 8 | 10 |
| NASH-4 | 1:3 | 3:1 | 5 | 10 | 0 | 10 | 6 | 10 |
| NASH-5 | 1:4.5 | 3:1 | 10 | 10 | 0 | 15 | 7 | 10 |
| NASH-6 | 1:6 | 3:1 | 15 | 10 | 0 | 20 | 8 | 10 |

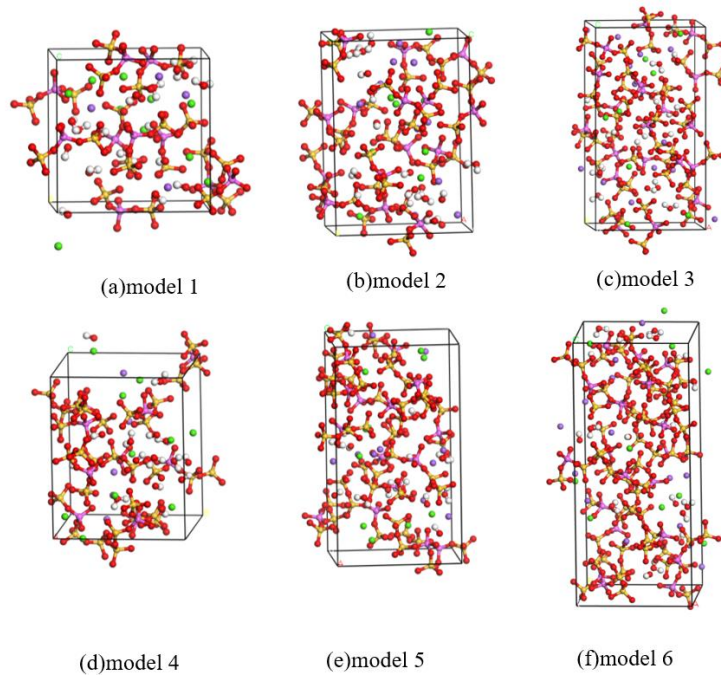


Figure 2: The structure model of geopolymer gel

MECHANICAL PROPERTIES OF MOLECULAR STRUCTURE OF GEOPOLYMER GEL

The mechanical properties program in the *Focrcite* module can be used to simulate and calculate the elastic modulus of the geopolymer gel system. The mechanical properties of the optimized structural model can be calculated under the *Compass* force field, and compared with the simulation results of the *Universal* force field. The simulation results of the elastic modulus after NVT MD optimization are shown in Table 3.

Luo et al.(2020) used nanoindentation technology to test the micromechanical properties of fly ash-based polymers and calculated the elastic modulus of amorphous NASH gel to be 47.2GPa. By comparison, it can be seen that the simulation value of the Universal force field is larger than that of the *Compass* force field, but the simulation results of both methods are consistent with the actual test results. Due to differences in the initial model, types, and proportions of oligomers, and ensemble parameter settings, the simulation results of molecular dynamics models may be affected to a certain extent. Different calcium silicon ratios and silicon aluminum ratios affect the products of geopolymer reactions, such as PS, PSS, and PSDS (Davidovits, 2020). These different types of geopolymers exhibit significant differences in structure and performance. From the results, the elastic modulus of NASH gel decreases with the decrease of calcium silicon ratio.

Table 3: The elastic modulus (GPa) of the geopolymer structure model

| Structure type | Under <i>COMPASS</i> | Under <i>Universal</i> (Wang Q et al., 2020) |
|----------------|----------------------|--|
| Model 1 | 39.01 | 46.45 |
| Model 2 | 33.53 | 41.91 |
| Model 3 | 28.84 | 33.54 |
| Model 4 | 36.40 | - |
| Model 5 | 27.62 | - |
| Model 6 | 22.96 | - |

RADIAL DISTRIBUTION FUNCTION OF MOLECULAR STRUCTURE OF GEOPOLYMER GEL

The radial distribution function (RDF) (Allen & Tildesley, 2017), as an effective parameter for characterizing the structural characteristics of a system, can intuitively reflect the structural features of the system. Its physical meaning is the ratio of the local atomic density of the system to the average density of the system. When MD simulation is carried out for the gel structure model, the system movement trajectory can be obtained, and the RDF of the system can be calculated from the movement trajectory of the structure model system. The RDF $g(r)$ is commonly used to characterize the spatial correlation between atoms, which represents the ratio of local density to the overall density of atoms. If there is a clear peak in the radial distribution function, it indicates stable nonbonding interactions between atoms, and the peak position can be used to analyze bond length information. The RDF $g(r)$ is as follows:

$$g(r) = \frac{dN}{\rho^4 \pi r^2 dr} \quad (1)$$

Where N is the total number of atoms of this class; ρ is the system average density of this type of atom; r is the distance from the reference atom to other atoms.

For NASH, an amorphous system, due to its close-range order and long-range disorder, its radial distribution function usually only has peaks within the close range. When the radius approaches infinity, the local atomic density of the entire system is equal to its average density, and the value of the radial distribution function will tend to be 1. The difference in radial distribution function caused by this structural difference can serve as an important reference for determining the crystallization state of the system.

The total RDF of the NASH gel system in the range of 0~1.0 nm, as well as the RDF of the H-O bond, Si-O bond, Al-O bond, and O-O bond in the system was obtained through *Forcite* module calculation, as shown in Figure 3. As shown in Figure 3 (a), the total RDF of NASH gel will only have an obvious peak in the short range. With the increase of atomic spacing (>0.35 nm), the peak will gradually disappear. In a larger radius range, its value will gradually tend to 1, which is consistent with the characteristics of short-range order and long-range disorder that the amorphous system structure should show. From the radial distribution function diagrams of each atomic pair (Figure 3 (b) - (d)), it can be observed that the first peak positions of H-O bond, Si-O bond, Al-O bond, and O-O bond is around 0.097, 0.161, 0.177, and 0.263 nm, respectively.

White et al. (2011) used neutron scattering to determine the structural factors of metakaolin-base polymers in a 90-day-old and calculated the corresponding RDF curve. The comparison between the calculated results and the simulated values in this paper is shown in Table 4. According to Table 4, the RDF values obtained from the simulation calculations in this paper are in good agreement with the experimental values of White et al. The model Al-O bond, O-O bond, Si-O bond, and Ca-O bond are close to the experimental values, so the structure model constructed under the COMPASS force field and obtained by structural optimization and molecular dynamics simulation meets the structural requirements of geopolymer gel.

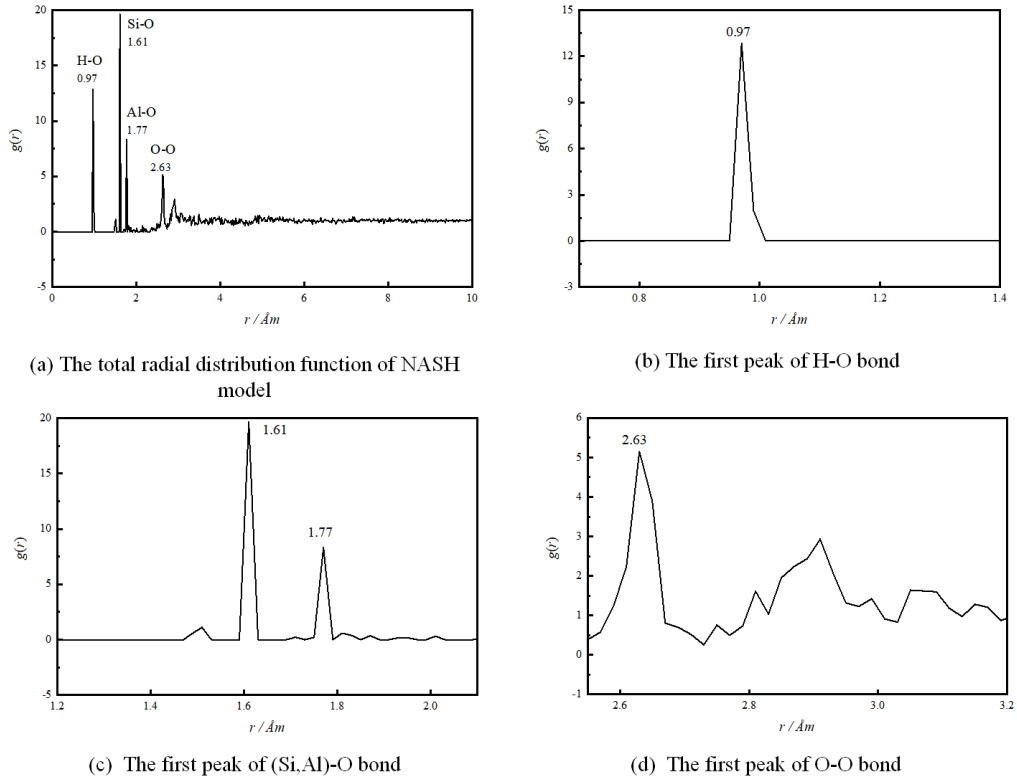


Figure 3: RDF of NASH gel system, (a) is the total RDF of NASH, the peak appears between 0.97 and 3.5 Å, (b) is the first peak of H-O bond, (c) is the first peak of (Si, Al)-O bond, (d) is the first peak of O-O bond,

Table 4: RDF value of each atom pair of NASH gel /nm

| Atomic pair type | H-O | Si-O | Al-O | O-O |
|--|-------|-------------|-------------|-----------|
| Experimental value (White et al., 2011) | 0.095 | 0.163~0.167 | 0.175~0.180 | 0.23~0.50 |
| This study | 0.097 | 0.161 | 0.177 | 0.263 |

XRD ANALYSIS

Because NASH gel is amorphous at room temperature and has low crystallinity, in its XRD pattern, the diffraction peak widens and forms a dispersion peak, which is generally distributed in the range of 2θ from 10° to 30° . The XRD patterns of amorphous NASH gel were calculated by *Materials Studio* software and compared with the XRD analysis results of UMK geopolymer samples cured for 28 days (Y. Luo, Jiang, et al., 2022). In the 28-day UMK geopolymer, the main component is an amorphous phase (2θ is the dispersion peak in the range of $20\sim 35^\circ$). It is believed that the dispersion peak in this range is caused by the amorphous NASH gel. In the simulated XRD spectrum of NASH gel in this study, the dispersion peak is distributed in the range of 2θ from 10° to 40° , which indicates that NASH gel is an amorphous substance. But there is a deviation of about 10° from the dispersion peak in UMK geopolymer. The occurrence of this difference is due to the superposition of diffraction peaks of impurity minerals and dispersion peaks of amorphous phases in UMK geopolymers, resulting in a shift of

dispersion peaks towards higher angles. The crystals used in simulation calculations are affected by simulation conditions, which may cause fluctuations or noise in the XRD pattern of the simulation results. However, in real experiments, due to the uniformity and anisotropy of the samples, as well as differences in sample preparation, some peaks may become weaker or stronger. If some peaks become weaker, they may disappear from the instrument noise, thereby reducing the number of peaks.

As shown in Figure 4, the simulated XRD patterns of NASH gel are consistent with the test values, indicating that the microstructure of the amorphous NASH gel system established in this study is consistent with the actual situation.

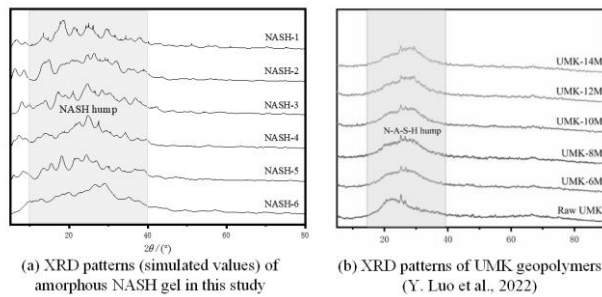


Figure 4: XRD patterns of amorphous NASH gel (simulation value) and UMK geopolymer, molecular models showing different combinations of geopolymers exhibit distinct crystal structure characteristics, with simulated and experimental dispersion peaks ranging from 10 ° to 40 °

DISCUSSION ON THE LIMITATIONS OF THE MODEL

Although the model in this study showed good consistency with the experimental results in the literature in terms of radial distribution function (RDF), XRD simulation pattern, mechanical properties, etc., it still has some limitations. First of all, this study assumes that the initial geopolymer gel structure model constructed can reasonably reflect the microstructure characteristics of actual materials. This includes correct atomic ratios, chemical bond types, and spatial network structures. However, due to limitations in real-world computing resources, we have reduced the model size to simplify calculations, which may result in bias when evaluating mechanical performance. Based on limited simulation research data, the selection of oligomer molecular models has a single type, short molecular chains, and some discrepancies with real polymers, which increases the uncertainty of the results. Future research should focus on improving models to more comprehensively reflect the complexity of real systems. Secondly, this study assumes that the selected molecular dynamics simulation parameters (such as force field, temperature, pressure, time step, etc.) can accurately describe the dynamic behavior of geopolymer gel. The selection of these parameters is based on existing research results, ensuring the applicability and correctness of the simulation results. In the future, various parameter adjustments will be made to improve the accuracy of the simulation.

The results of this study have certain significance for the field of sustainable materials science and engineering. By revealing the performance of polymer molecular models based on fly ash with different calcium-to-silicon and silicon-to-aluminum ratios, a theoretical basis can be provided for the development of more efficient and environmentally friendly geopolymer materials. This study is also consistent with the current trend in materials science to regulate material properties through microstructure design.

CONCLUSION

This study successfully verified the accuracy of the initial structure model of fly ash geopolymer gel based on the experimental and existing simulation data and provided a clear perspective for an in-depth understanding of the relationship between the structure and performance of geopolymer gel at the molecular level. This contribution provides significant reference value for the development of high-performance and environmentally friendly geopolymer materials and helps promote innovation and sustainable development in the fields of architecture and materials science.

Based on the initial structural model constructed concerning the experimental data, according to the structural characteristics of fly ash geopolymer gel system, Na atom, H₂O molecule, Si₂AlO₁₀, and Si₃AlO₁₃ group are selected as the basic unit to construct the geopolymer gel model NASH. According to the movement track of the system in the simulation process, several optimization simulation operations were carried out, and the radial distribution function (RDF), XRD simulation atlas, mechanical properties, and other relevant parameters of the NASH gel system were calculated. The good agreement between these parameters and experimental data proves the effectiveness and reliability of the model. The establishment of this model provides important experience for the subsequent research on the mechanical properties, durability, and environmental adaptability of geopolymer gel. Based on the NASH gel model established in this study, we can further explore the microstructure evolution of geopolymer gel under different process conditions, and optimize its mechanical properties and environmental adaptability.

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THE DEVELOPMENT OF GREEN INFRASTRUCTURE IN MODERN BUILDINGS

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ABSTRACT

Since the 20th century, sustainable development has evolved in architectural design, and green infrastructures of plant-covered buildings have become popular. With the support of technology, various types of green infrastructures such as green roofs, green facades, and vertical gardens have become an integral part of urban architecture as a new architectural element. The green appearance of buildings can not only regulate the temperature and air quality, and control the amount of light inside the building, but also be a new architectural aesthetic element. However, the development of green infrastructure technology has not yet achieved the expected results in construction practice, and many existing vegetation buildings do not show qualified ecological and economic effects. As an emerging architectural approach, the natural elements of vegetation conflict with the elements of modern cities, and designers need to pay more attention to solving this problem and improve the user's participation and sense of identity in the architectural space.

Keywords:

Cities, Modern Buildings, Green Infrastructure, Green Roofs, Green Walls

GREEN INFRASTRUCTURE: HISTORICAL BACKGROUND, CONCEPT, AND ROLE IN MODERN CITIES

Historical Development of Green Infrastructure

The history of green infrastructure is extensive, dating back to ancient civilizations' exploration of integrating urban environments with nature. In ancient Babylon, the Hanging Gardens demonstrated how early humans could blend natural beauty into urban structures. Over time, this concept continued in the urban landscape designs during the Renaissance in Europe, such as the rooftop gardens in Italy. As the industrial era began and urbanization brought environmental challenges, the value of green spaces was reevaluated. In the 20th century, with the rise of the environmental movement, green infrastructure was recognized as a key component of urban sustainability (Loder, 2014). Today, with the acceleration of global urbanization, green infrastructure plays an essential role in mitigating urban heat island effects, improving air quality, and providing habitats for biodiversity (Loder, 2014).

Contemporary Development and Application of Green Infrastructure

The development of contemporary green infrastructure reflects a comprehensive consideration of environmental, social, and economic sustainability (Ali & Kheir, 2012). In modern cities, green roofs and walls serve not only as ecological engineering practices but also integrate with architectural aesthetics and urban design. For instance, Singapore's garden city concept, New York's High Line Park, and other cities' green corridors and park networks are exemplary applications of innovative green infrastructure. These projects illustrate how green infrastructure can enhance the quality of life for urban residents while promoting ecological balance and economic development in cities.

Definition and Classification of Green Infrastructure

Green infrastructure is defined as a series of natural or quasi-natural elements that work together to provide ecological services to cities, promoting social welfare and economic growth. These elements include, but are not limited to, green roofs, green walls, rain gardens, urban wetlands, and community gardens. Green roofs can be divided into intensive and extensive types based on the density of vegetation and the complexity of maintenance (Zhang, 2004). Green walls and vertical gardens utilize the vertical space of buildings to increase urban green space. Rainwater harvesting systems collect and reuse rainwater, reducing urban flood risks and replenishing groundwater resources.

Classification of green infrastructure in buildings

Green infrastructures can be divided into two categories, horizontal greening devices, and vertical greening devices, according to the direction and location of placement (Gao, 2018). Horizontal greening includes green roofs and elevated forests, while vertical greening includes green facades, green walls, green terraces, and vertical forests (Zhang, 2004). Among horizontal greening, green roofs were the first form of green infrastructure to be applied to buildings, and are a form of roof with planting and planting bases. Depending on parameters such as the depth of the medium, the size of the roof, and the frequency of use, green roofs can be categorized into intensive green roofs and extensive green roofs. This type of green system can play an ecological role in the city, including reducing the urban heat island effect and adjusting the internal climate of buildings.

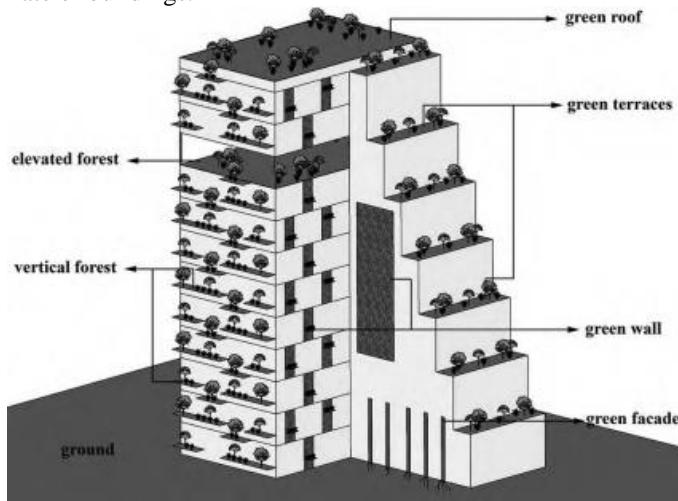


Figure 1: Location of applications in green infrastructure buildings
(Image source : https://www.archdaily.cn/cn/778006/bosco-verticale-boeri-studio?ad_source=search&ad_medium=projects_tab)

Green infrastructure, represented by green roofs and green facades, can be traced back to the sky gardens of the ancient Babylonian period. After the rise of Modernism, architects conducted various studies on green roofs and gardens that could be used by residents, and horizontally oriented green roofs were widely practiced. By the end of the 20th century and the beginning of the 21st century, green infrastructure was used to challenge the green facade as a new urban element to improve the micro-environment in the production of new buildings as well as in the restoration of old ones. Furthermore, the conservation of industrial heritage culture and the revitalization and urban renewal of industrial landscapes play a crucial role in achieving sustainable and prosperous growth in modern communities (Yi & Golnoosh, 2022).

KEY COMPONENTS OF GREEN INFRASTRUCTURE

Green infrastructure's key components, such as green roofs, walls, and rainwater harvesting systems, each play a critical role in urban sustainability and require detailed discussion and careful planning.

Green Roofs

The design of green roofs must take into account the load-bearing capacity of the roof structure to ensure it can support the weight of the soil, plants, and additional elements like walkways or seating areas (Sun, 2023). Waterproofing and drainage systems are essential to prevent water damage to the building and to ensure excess water can be effectively managed. The selection of plants should be based on their ability to thrive in the roof's specific conditions, including the depth of the growing medium, exposure to sunlight, and local climate adaptability. Intensive green roofs, which support a wide variety of plant life, offer significant ecological and recreational benefits, such as enhanced biodiversity, improved insulation, and amenity spaces for occupants. However, these roofs require more frequent maintenance and higher initial investment. In contrast, extensive green roofs, with their lower maintenance needs and cost-effectiveness, are favored for their simplicity and the benefits they provide in terms of reducing heat island effect and managing stormwater runoff.

Green Walls

Green walls, also known as living walls, introduce vertical greenery to building facades. The design of green walls must consider the structural integrity of the wall to support the weight of the plants and the hydroponic or soil-based systems used (Lu, 2016). Irrigation systems must be carefully planned to ensure even distribution of water and nutrients to the plants, which may vary with seasonality and plant species. Aesthetic considerations are also paramount; the design should complement the existing architecture and provide visual harmony with the surrounding urban landscape. Green walls contribute to improved air quality, noise reduction, and aesthetic enhancement of urban spaces.

Rainwater Harvesting Systems

The design of rainwater harvesting systems involves assessing the catchment area for collecting rainwater, which could come from rooftops or other surfaces. The storage capacity must be sized appropriately to handle the volume of water collected during peak rainfall events (Zhang, 2022). Filtration and treatment technologies are necessary to ensure the collected rainwater is suitable for its intended use, whether for irrigation, toilet flushing, or even potable uses after proper treatment. The reuse strategies for harvested rainwater should be clearly defined, taking into account local water demand and opportunities for integration with existing water systems.

In summary, the detailed discussion of green infrastructure components highlights the multifaceted considerations inherent in their design and implementation. Each component, from green roofs to walls and rainwater harvesting systems, must be carefully planned to address technical, environmental, and aesthetic challenges. By doing so, these green infrastructure elements can significantly contribute to the sustainable development of urban environments, enhancing their resilience, live ability, and visual appeal.

SELECTED CASE STUDIES

This study delves into a series of representative cases of green infrastructure, highlighting the renowned Bosco Vertical residential project as a prime example. Located in Milan, Italy, Bosco Vertical was designed by architect Stefano Boeri. The project has gained international acclaim for its innovative concept of vertical forests, where the exterior walls of the building are enveloped by a multitude of plants, aiming to create an eco-friendly living environment.

Table 1: Information about Bosco Verticale

| Feature/Data Point | Description/Value |
|---------------------------------|--|
| Project Name | Bosco Verticale (Vertical Forest) |
| Location | Porta Nuova area, Milan, Italy |
| Building Type | Residential Towers |
| Architect | Stefano Boeri Architects |
| Tower Heights | 80 meters and 112 meters |
| Total Number of Trees | 800 trees |
| Plant Species | 480 large trees, 300 small trees, 15,000 perennials/ground cover plants, 5,000 shrubs |
| Vegetation Area | Equivalent to 30,000 square meters of woodland and undergrowth |
| Urban Footprint | 3,000 square meters |
| Building Function | To limit urban sprawl, providing greenery equivalent to 50,000 square meters of single-family houses |
| Facade Features | Large staggered and overhanging balconies (about 3 meters deep), porcelain stoneware finish, incorporating the typical brown color of bark |
| Seasonal Plant Variation | Multi-colored cyclical and morphological changes, creating a rainbow landmark effect in every season |
| Awards | 2014 International Highrise Award from Deutsches Architekturmuseums in Frankfurt 2015 CTBUH Best Tall Building in the World from the Council on Tall Buildings and Urban Habitat at Chicago's IIT |
| Plant Maintenance | "Flying Gardeners" team, using mountaineering techniques, annual pruning and plant checks |
| Irrigation System | Centrally monitored system, using filtered effluent from the towers |
| Animal Habitat | About 1,600 species of birds and butterflies, an outpost for spontaneous flora and fauna recolonization in the city |

Notes:

- The data in the table is organized based on the provided information, reflecting the ecological, social, environmental, and economic impacts of the Bosco Verticale project.
- The project not only provides rich ecological benefits, such as a habitat for biodiversity and improved microclimate, but also has received internationally recognized awards, becoming a symbol of the city.
- The selection and distribution of plants consider aesthetic and functional criteria to adapt to the direction and height of the facades, ensuring the ecological benefits and visual appeal of the building.

- Maintenance and greening operations are managed at the condominium level to maintain the balance between humans and plants, with regular pruning and plant checks carried out by a specialized team.

Innovative Design and Technical Implementation

The Bosco Vertical project exemplifies the fusion of architecture and nature, pushing the boundaries of urban habitat design. Each tower of the Bosco Vertical is a living testimony to how green infrastructure can be integrated into the very fabric of residential buildings. The design incorporates a variety of plant species that are native or adapted to the local climate, ensuring the resilience and sustainability of the green facades. The technical implementation involves complex irrigation systems that are both energy-efficient and reliable, ensuring the survival and growth of the plants despite the challenging vertical environment.

Environmental Benefits

The environmental benefits of Bosco Vertical are manifold. The dense vegetation on the building's facades provides insulation, reducing the need for artificial heating and cooling and thus lowering the building's energy consumption. Additionally, the plants absorb carbon dioxide while releasing oxygen, contributing to improved air quality in the urban environment. The presence of vegetation also helps to mitigate the urban heat island effect, as the plants provide shade and transpire water, lowering the ambient temperature.

Impact on Residents' Quality of Life

The Bosco Vertical project has had a profound impact on the quality of life for its residents. Living in close proximity to nature has been linked to reduced stress levels and improved mental well-being (Du, 2006). The green spaces offer a serene environment that buffers residents from the hustle and bustle of city life. Moreover, the presence of green infrastructure encourages a more active lifestyle, with residents being more likely to engage in outdoor activities and social interactions within their community.

Plant Selection and Maintenance Management

The selection of plant species in Bosco Vertical was carefully considered to ensure they could thrive in the vertical environment and contribute to the overall ecosystem services. The plants were chosen for their adaptability to the local climate, resistance to wind, and ability to flourish with the automated irrigation system. Maintenance management is a critical aspect of the project, with a dedicated team responsible for the upkeep of the green facades. This includes regular checks on plant health, pruning, and replacement of any deceased flora (Yusuf & Manteghi, et al, 2021).

Adaptability to Local Climate and Culture

The Bosco Vertical project demonstrates a high degree of adaptability to the local climate and culture. The design takes into account Milan's climate, choosing plants that can withstand the seasonal variations. Moreover, the project has become a cultural symbol, reflecting the city's commitment to environmental sustainability and innovation. It has inspired other cities and developers to explore similar green infrastructure projects, showcasing the potential for vertical forests in urban landscapes worldwide.

The Bosco Vertical case study provides a comprehensive insight into the practical application of green infrastructure in urban settings. It highlights the potential of innovative design, the importance of environmental considerations, and the significant impact on residents' quality of life. As urban

populations continue to grow, projects like Bosco Vertical offer a viable model for integrating green infrastructure into cityscapes, promoting ecological harmony and enhancing the well-being of urban dwellers.

This detailed exploration of Bosco Vertical and similar cases sets a benchmark for future green infrastructure projects, emphasizing the need for creativity, technical proficiency, and a deep understanding of local contexts. It is through such projects that we can envision a future where urban environments are not just places of concrete and steel but are also habitats rich in greenery and life.

PROBLEMS WITH GREEN INFRASTRUCTURE IN HUMAN HEALTH IMPACT STUDIES

Large-scale green infrastructures can provide positive social benefits by lowering local temperatures, reducing air pollution, and mitigating conflicts between urban development and natural ecology (Gao, 2018).

At the same time, some data in the literature suggest that green infrastructure may affect indicators of chronic disease morbidity and mortality. In cities, the distribution of green infrastructure affects the number of respiratory diseases in children. The health impacts of green infrastructure in these studies lacked direct and clear quantitative indicators, and there was no suitable system for evaluating their effects. When data were obtained in the studies, the period over which the data were available was small, making it difficult to establish comparisons over a long period (Sun, 2023).

In health impact studies, researchers often focus on large, urban-scale green infrastructure. These large-scale green infrastructures tend to refer to specific tree benefits, such as extensive vegetative cover, canopy shading, or traditional parks, rather than more localized green infrastructures that speak directly to building interventions, such as green wall systems, green facade systems, and rooftop green roofs that are attached to the building envelope.

There is a lack of research on the health impacts of green infrastructure, as represented by green roofs and green walls. These green facilities have different characteristics in different categories and are difficult to characterize systematically. At the same time, these green infrastructures are often small in scale, affecting only the people in and around the building, and it is difficult to measure the health impacts of these facilities (Lu, 2016).

In terms of mental health, small-scale green infrastructures placed between or within buildings had a positive impact on users and residents. With green infrastructure such as green roofs, vertical forests, and green walls, many green spaces can be created between buildings. These green spaces can be flexibly located in all parts of the building, making green gardens easily accessible to users in every area. These green gardens can be used to calm the users and have a positive effect on stress relief, mood stabilization, and physical and mental well-being. However, there is a lack of reasonable quantitative criteria for validating the psychological healing effects of green infrastructure.

ECOLOGICAL AND ECONOMIC BENEFITS OF GREEN INFRASTRUCTURE

Ecological Benefits of Green Infrastructure

In addition to the healing effect on the occupants, green infrastructure also has a regulating effect on the ecosystem. Bosco Vertical is a residential building with extensive green infrastructure, as shown in Figure 2, and the building in Milan has been certified by Leadership in Energy and Environmental Design for its extensive use of vertical forests as part of its green infrastructure. The building was expensive to construct and maintain. For the plants in the building to grow properly, the owner had to pay a large amount of money to customize a special irrigation system and observation equipment. For day-to-day maintenance and use, the operator needed to hire a special team of horticulturists to care for and prune

the trees in the building to ensure that the occupants of the residential building had a normal living experience. These horticulturists are specially trained for this unique building and are required to work at heights during routine maintenance, as shown in Figure 3. From the support systems to the training of the professionals, Bosco Vertical's use of green infrastructure like vertical forests may seem like a good way to save energy, but it comes at a high additional cost.



Figure 2: Bosco Vertical

(Image source : https://www.archdaily.cn/cn/778006/bosco-verticale-boeri-studio?ad_source=search&ad_medium=projects_tab)



Figure 3: Landscaper working at heights

(Image source : https://www.archdaily.cn/cn/778006/bosco-verticale-boeri-studio?ad_source=search&ad_medium=projects_tab)

In addition, not all buildings with green infrastructure will achieve the desired ecological impact. The materials used in the construction and use of green infrastructure have an impact on the greening of a building throughout its life cycle. The environmental burden of green facade systems varies considerably depending on the material used, e.g., the use of more stainless-steel support systems can be more environmentally burdensome. Measures can be taken to reduce the environmental burden of some green facade systems, thereby reducing their energy consumption. For example, when designing green curtain wall systems, more water- and electricity-saving irrigation systems can be used, and appropriate plants and planting ratios can be selected according to the actual climatic environment of the site.

Economic Benefits of Green Infrastructure

Choosing locally appropriate green infrastructure can greatly enhance its ecological benefits throughout its life cycle. In their quest for advanced green and energy-efficient technologies and specific aesthetic effects, some owners and designers have transported special equipment from far away. The transportation process often incurs high costs and carbon emissions. When the equipment reaches the end of its useful life and needs to be replaced, it will impact the surrounding environment if it is not properly disposed of at the end-of-life stage. Considering the whole life cycle, the overall ecological and economic benefits of these green infrastructures are greatly reduced, and the cost savings of using some of the equipment far exceeds the total cost of construction, maintenance, and disposal of the equipment. Therefore, when selecting green infrastructure in the design phase, designers must prioritize locally available materials and equipment, and actively use local technologies and facilities.

Therefore, in-depth design of green infrastructure systems needs to consider the entire life cycle of the equipment, prioritize recyclable and reusable materials, and arrange for waste and recycling procedures before construction and after design. Moreover, Haruna and Manteghi et al. (2021) demonstrated that the integration of BIM technology in green building design can enhance the sustainability of construction projects and mitigate their environmental effects.

Green infrastructure is a flexible and versatile green building technology, and the use of different technologies for different environments can enhance the benefits of green infrastructure, but there is still a lack of emphasis on localization. Scholars need to work more closely with local communities to develop assessment tools that can be adapted to the context of urban development planning. Ideally, assessment tools should take into account all aspects of the city's characteristics. Each type of green infrastructure has its characteristics, aesthetic potential, and maintenance needs, and should be selected taking into account the characteristics of the building and the climate of the site (Zhang et al., 2022). Green infrastructure should not just be a decoration in the external space of the building, but when improving the image of the building facade, green curtain walls, green roofs, etc. should maximize the green benefits and achieve energy-saving effects, to maximize the economic benefits for the users.

GREEN INFRASTRUCTURE AND URBAN CONFLICTS

Green infrastructure, which consists of natural plants, is a growing aesthetic symbol. However, it has several difficulties when trying to be incorporated into the modern constructed environment. Therefore, effective planning and administration are crucial. Peng et al. (2023) conducted a study that highlighted the benefits of integrating qualitative and quantitative methodologies in analyzing building design risks. This approach enhances the theoretical foundation of risk management in construction projects. Green infrastructures can bring significant visual character to a building's exterior, transforming the cityscape and enhancing urban aesthetics while creating energy-efficient and environmentally friendly buildings. The 26-storey EDITT building in Singapore, designed by architects T R Hamzah and Yeang, has won awards for eco-design, and Ali et al. argue that the use of extensive green terraces is environmentally beneficial as it increases local biodiversity and restores ecosystems (Ali & Kheir, 2012). However, in the

opinion of Tabb et al., the use of green infrastructure in the building is "a tendency of the architectural order and tectonic system to dominate the natural system in a large, rigid and unnatural way".

While the widespread use of green infrastructure in architecture is largely due to its environmental restorative effects, little research has examined the aesthetic preferences of city dwellers for green infrastructure and how underlying cultural and historical factors may influence perceptions of other urban natural systems (Dut et al., 2006). Loder used a phenomenological methodology to study office workers in a North American city. Some of the residents did not recognize green roofs as a natural form of construction, but still felt relaxed and calm, and the aesthetics of the city's previous sense of control conflicted with the targeted ecological image. The new landscape created by the green plants growing on top of the buildings is a great visual shock to the residents who are used to the bare surfaces of the buildings in the city. This disparity can lead to a blurred response to the natural areas of the city. As an emerging green space paradigm, green roofs lack the symbolic meaning of mountains and forests, and designers are keen to mimic natural environments. Loder's study is limited to green roofs as a type of green infrastructure, and there is limited research on whether people feel the same conflict with other types of green infrastructure (Loder, 2014).

CONCLUSION

As a new green building technology, green infrastructure has great potential for development. Nowadays, there are still many challenges to be solved to maximize the use of green infrastructure. As one of the solutions to the problems of nature and urban development, green infrastructure needs to be developed in a balanced way in terms of health benefits, ecological benefits, and economic benefits. In addition, a good management and evaluation system is also an important way to optimize the application of green infrastructure.

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STUDY ON THE INFLUENCE OF COARSE AGGREGATE TYPES ON THE BONDING PROPERTIES OF HIGH-STRENGTH CONCRETE-FILLED STEEL TUBE

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ABSTRACT

This paper presents the results on the influence of coarse aggregate types on the bonding properties of high strength concrete filled steel tube. In order to study the difference of interface bonding properties between square and circle steel tube high-strength concrete with different coarse aggregate types, a total of 18 specimens were designed and prepared for steel tube push-out tests. The variation parameters of concrete strength grade, coarse aggregate type and steel tube section shape are mainly considered for the tests. Through the experiments, the failure patterns of samples are observed, analyzed and recorded. The load-displacement curve and characteristic point parameters are sketched and analyzed too. Whereas the factors affecting the failure process and bonding properties of the concrete-filled steel samples are studied. The results show that for square specimens, the ultimate bond strength and residual bond strength of natural crushed stone specimens are the largest, and the residual bond strength of crushed pebble specimens is the smallest. For circle specimens, the ultimate bond strength of natural crushed stone specimens is the highest, and that of crushed pebble specimens is the least. Under the condition that the bond area is close to the same (the difference of bond area of specimens is less than 10%), the ultimate bond strength of the square specimen is mostly higher than that of the circle specimen, and the residual bond strength of the circle specimen is higher than that of the square specimen. Thus, it can be concluded that the ultimate bond strength and residual bond strength are vary depending on the concrete strength grade and coarse aggregate types.

Keywords:

Coarse aggregate type; concrete filled steel tube; bond property

INTRODUCTION

As a kind of structural material, concrete filled steel tube (CFST) has the advantages of high strength, excellent durability, good resistance to wind and earthquake, etc., and has been widely used in the field of construction engineering and infrastructure. Moreover, the characteristics of large heat capacity and good thermal insulation performance of concrete filled steel tube can effectively reduce the energy consumption of buildings, improve the energy-saving performance of buildings, and meet the requirements of modern buildings for energy conservation and environmental protection. In recent years, the application of concrete filled steel tube in the field of energy saving and environmental protection buildings has gradually increased. With the continuous development of science and technology and the progress of engineering technology, the application prospect of concrete-filled steel tube in the future will be broader. In addition, there is a need to investigate the influence of coarse aggregate types of high strength concrete filled steel tube due to limited source of knowledge available.

The bond mechanism of concrete-filled steel tube (CFST) is complicated, there are many uncertain factors affected by various parameter variables, and different types of concrete materials have different bond properties. In recent years, scholars have conducted a lot of research on the bonding properties of concrete-filled steel tube specimens of different types of concrete materials, such as ordinary concrete (Norul Wahida et al, 2023a; Wang et al., 2022), recycled aggregate concrete (Norul Wahida Kamaruzaman, 2023b; Chen et al., 2022; Lyu & Han, 2019; Zhao et al., 2021), high-strength concrete (Cao et al., 2023; Dong et al., 2020a, 2020b), steel fiber concrete (Li et al., 2020; Lu et al., 2018; Kong

Linjie, 2023), machine-made sand concrete (Guan et al., 2019; SHA Meng et al., 2023), ultra-high performance concrete (Xie et al., 2023), etc., and obtained rich test results, which laid a good foundation for promoting the application of concrete-filled steel tube.

However, as a common natural material in nature, there are few researches on the bonding properties of concrete-filled steel tube (CFST), and their application scope is relatively small. At present, the pebbles and crushed pebbles in the river are mainly made into sand by machine production and applied in the engineering field. In addition, the application of filler materials with roadbed engineering, construction of horticultural roads and landscaping works. These engineering application scenarios are far from giving full play to the advantages of pebbles and crushed pebbles. In this paper, based on the performance advantages of concrete-filled steel tube composite structure, in order to expand the application scenarios of pebbles and crushed pebbles, crushed pebbles, natural pebbles and natural gravel are taken as coarse aggregates, and the bonding properties of concrete-filled steel tube specimens made of different coarse aggregates are compared to provide references for expanding their application scope.

METHODOLOGY

The design of the specimen takes into account three parameters: coarse aggregate type (crushed pebble, natural pebble, natural stone), concrete strength grade (C65, C75, C85), and steel tube section shape, according to the principle of approximately equal bonding area (the difference of specimen bonding area is less than 10%). 18 specimens of square and circle straight welded steel tubes with different side lengths and diameters were selected for testing. Steel tube length 400mm, thickness 4mm. The upper and lower ends of the steel tube are determined as the loading end and the free end. A 50mm space is reserved at the free end without pouring concrete, and a 10mm wide notch is opened by mechanical machining. The steel sheet is consolidated with the internal concrete through the notch as a whole, which is used as a measuring point for measuring the slip amount of the free end concrete.



Figure 1: Coarse aggregate used in the test

Push-out test

RMT-301 rock and concrete mechanics test system was used to load the specimens. In order to obtain the load slip curve of the whole process of the test, the test adopts the displacement-controlled loading system, and the loading rate is 0.3mm/min. When the test load reaches about 10mm at the free end, the load does not change significantly, and the test is considered to be over.

ANALYSIS

Test phenomena

After the formal loading starts, the loading end and the free end of the steel tube specimen slip almost simultaneously. At the initial stage of loading, with the increase of load, the slippage keeps increasing, and the relationship between load value and slippage is almost linear. The slip rate of the loading end is faster than that of the free end, and the slip amount is larger. During the sliding process of the specimen, the sound of concrete crushing like electrostatic "squeaking" is emitted from time to time. At this point, the load rises rapidly. With the further increase of slip and load, the natural pebble and crushed pebble specimens will break out the "dong dong" sound, and the "dong dong" sound of natural pebble specimens is larger than that of crushed pebble specimens. The "thumping" sound of the square steel tube specimen is larger than that of the crushed pebble specimen. The natural gravel specimen did not make a "knock" sound. After that, the load peak point (square specimen) or inflection point (circle specimen) appeared, and the load value and slip amount showed a nonlinear relationship, the load value of the square specimen appeared a decreasing stage, the circle specimen remained stable or increased slightly, and the slip difference between the loading end and the free end gradually decreased until the synchronization was maintained, and the core concrete was pushed out. After the loading was finished, the loading pad was removed, and it was observed that the core concrete at the loading end was concave inward, and the concrete "crushed" occurred along the loading pad, the outer wall of the steel tube did not bulge significantly outward, and the hollow part of the steel tube at the free end did not buckle.

Load-slip curve

Figure 2 shows the load-slip curve of square and circle representative specimens. It can be seen that the curves of the loading end and the free end are approximately the same. Summary and analysis of curve characteristics and reference results (KE Xiaojun et al., 2015; SHA Meng et al., 2023; Wang et al., 2022; XU Jinjun et al., 2013), the curve can be simplified into a fast-rising section, a falling section (an inflection point rising section) and a horizontal section.

Straight ascending section

In the process of pushing out the specimen, the slip first occurs at the loading end of the specimen and gradually develops to the middle and free end of the specimen with the increase of the load. The interface bonding force is composed of chemical bonding force, mechanical biting force and friction force on the contact interface. Because the dry shrinkage of high strength concrete is larger than that of ordinary concrete, the chemical bonding force is smaller. At the initial stage of loading, the adhesive force is mainly provided by chemical bonding force and mechanical biting force. With the increase of slip, the chemical bonding force is gradually lost, and the mechanical bite force and friction force between the interfaces are gradually increased. When the combined force reaches the maximum, the pushing load reaches the ultimate load.

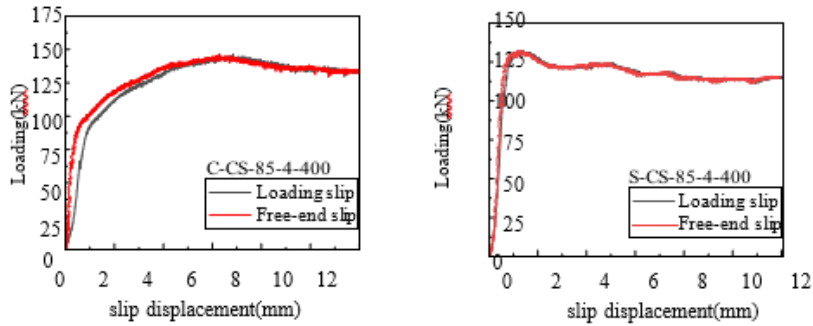


Figure 2: Load-displacement curves of specimens

Down section (inflection point up section)

When the ultimate load is reached, the steel tube wall is squeezed by the core concrete and tends to bulge outwardly. If the steel tube wall has insufficient action on the concrete hoop, and it bulges outwardly, the mechanical biting force and friction resistance will decrease. The effect of square specimen on concrete hoop is weaker than that of circle specimen. For this reason, the bond strength of the square specimen decreases, and the load-slip curve of the circle specimen shows a declining section, while the load-slip curve of the circle specimen shows a slightly stable rising section, but the slope of the curve decreases gradually.

Horizontal segment

With the continuous loading, the interface bonding force is mainly balanced by friction resistance and tends to be stable, and the load-slip curve is horizontal or close to the horizontal line. Characteristic value of load-slip curve

See the literature (Shakir-Khalil H, 1993; Viridi & Dowling, 1980), combined with the literature (CHEN Zongping & ZHOU Ji, 2020), defined the interfacial shear stress corresponding to P_u and P_r as the ultimate bond strength τ_u and the residual bond strength τ_r . Based on load-slip curve, test characteristic values of specimens are shown in Table 1 and Table 2. Among them, the load value corresponding to the peak point of the curve is the ultimate load P_u , and that corresponding to the approximate horizontal segment is the residual load P_r .

Table 1: Test characteristic values of square concrete-filled steel tube specimens

| Specimen number | P_u /kN | P_r /kN | τ_u /MPa | τ_r /MPa |
|-----------------|-----------|-----------|---------------|---------------|
| S1 | 96.54 | 91.29 | 0.62 | 0.58 |
| S 2 | 112.38 | 83.61 | 0.72 | 0.53 |
| S 3 | 100.92 | 81.54 | 0.64 | 0.52 |
| S 4 | 140.28 | 72.18 | 0.89 | 0.46 |
| S 5 | 113.52 | 94.14 | 0.72 | 0.60 |
| S 6 | 100.95 | 91.29 | 0.64 | 0.58 |
| S 7 | 119.52 | 94.83 | 0.76 | 0.60 |
| S 8 | 132.69 | 113.58 | 0.85 | 0.72 |
| S 9 | 137.64 | 104.01 | 0.88 | 0.66 |

The design requirements for the interface bond strength of concrete filled square steel tube are different in different countries and regions. Japan AIJ requires that the bond strength of rectangular concrete-filled steel tube is 0.15MPa (Recommendations for Design and Construction of Concrete Filled Steel Tubular Structure, 1997); The British BS5400 (Steel Concrete and Composite Bridges: Part 5: Code of Practice for the Design of Composite Bridges: BS 540025: 2005, 2005) and the European EC4 (Eurocode 4: Design of Composite Steel and Concrete Structures: Part 1-1:General Rules and Rules for Buildings: BS EN 1994-1-1:2004, 2004) both stipulate that its value is 0.40MPa. It can be seen from Table 1 that τ_u and τ_r of square tubular high-strength concrete with different coarse aggregate types meet the requirements of relevant specifications.

Table 2: Test characteristic values of circle concrete-filled steel tube specimens

| Specimen number | P_u /kN | P_r /kN | τ_u /MPa | τ_r /MPa |
|-----------------|-----------|-----------|---------------|---------------|
| C1 | 73.95 | 105.51 | 0.45 | 0.64 |
| C 2 | 81.57 | 142.89 | 0.49 | 0.86 |
| C 3 | 71.655 | 170.86 | 0.51 | 0.81 |
| C 4 | 104.19 | 141.66 | 0.63 | 0.85 |
| C 5 | 92.13 | 138.84 | 0.55 | 0.84 |
| C 6 | 87.6 | 125.67 | 0.53 | 0.76 |
| C 7 | 143.58 | 149.7 | 0.86 | 0.90 |
| C 8 | 98.58 | 136.98 | 0.59 | 0.83 |
| C 9 | 86.31 | 139.59 | 0.52 | 0.84 |

There is no uniform design standard value of bond strength between circle steel tube and concrete interface in the world, such as the design value in Asia is 0.225MPa (Recommendations for Design and Construction of Concrete Filled Steel Tubular Structure, 1997), and the design value in Europe is 0.40 MPa (Eurocode 4: Design of Composite Steel and Concrete Structures: Part 1-1: General Rules and Rules for Buildings: BS EN 1994-1-1:2004, 2004. It can be seen from Table 2 that τ_u and τ_r of circle tubular high-strength concrete with different coarse aggregate types meet the requirements of relevant specifications.

ANALYSIS OF INFLUENCING FACTORS OF BONDING PROPERTIES

Influence of coarse aggregate type on the bonding properties of square steel tube specimens

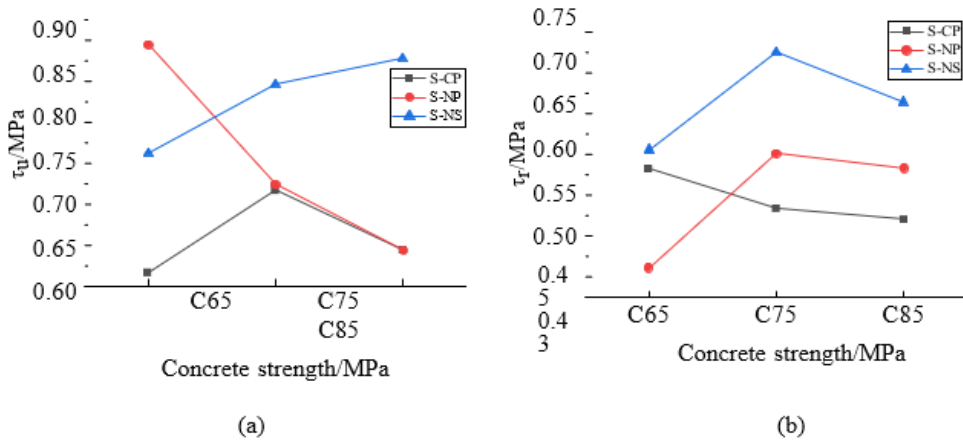


Figure 3: Influence of coarse aggregate type on the bonding properties of square steel tube specimens

The type of coarse aggregate has significant influence on the bonding properties of square specimens. It can be seen from Figure (a) that the ultimate bond strength of the natural gravel specimen is the largest, while that of the crushed pebble specimen is the smallest. The ultimate bond strength varies with the change of coarse aggregate type. When crushed pebbles are used as coarse aggregate, the ultimate bond strength increases first and then decreases with the increase of concrete strength grade, and the difference between the minimum value and the maximum value is 16.4%. When natural pebble is used as coarse aggregate, the ultimate bond strength decreases with the increase of concrete strength grade, and the difference between minimum and maximum value is 39.0%. When natural gravel is used as coarse aggregate, the ultimate bond strength decreases with the increase of concrete strength grade, and the difference between the minimum value and the maximum value is 15.2%.

It can be seen from Figure (b) that the residual bond strength of the natural gravel specimen is the largest, while that of the crushed pebble specimen is the smallest. There are two different changes of residual bond strength with the change of coarse aggregate type. When crushed pebbles are used as coarse aggregate, the residual bond strength decreases with the increase of concrete strength grade, and the difference between the minimum and maximum value is 12.0%. When natural pebble and natural gravel are used as coarse aggregate, the residual bond strength increases first and then decreases with the increase of concrete strength grade, and the difference between the minimum value and the maximum value is 30.4% and 19.8%, respectively.

Influence of coarse aggregate type on the bonding properties of circle steel tube specimens

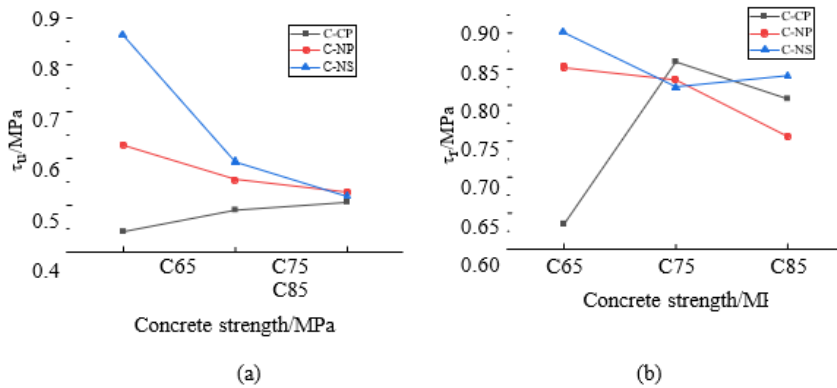


Figure 4: Influence of coarse aggregate type on the bonding properties of circle steel tube specimens

It can be seen from the figure that the type of coarse aggregate has a significant effect on the bond performance of the circle specimen. It can be seen from Figure (a) that the ultimate bond strength of the natural gravel specimen is the largest, while that of the crushed pebble specimen is the smallest. The ultimate bond strength varies with the change of coarse aggregate type. When crushed pebbles are used as coarse aggregate, the ultimate bond strength increases with the increase of concrete strength grade, and the change range of maximum and minimum values is only 14.0%. When natural pebbles and natural gravels are used as coarse aggregates in the concrete filled steel tubes, the ultimate bond strength of the concretes decreases with the increase of concrete strength grade. The maximum and minimum values change by 18.9% and 66.4%, respectively. It can be seen from Figure (b) that the variation law of residual bond strength with coarse aggregate type is relatively discrete, and the variation law of specimens with various coarse aggregate types is different. The residual bond strength of crushed pebble specimens varies greatly with the strength grade of concrete, up to 35%. The residual bond strength of natural pebble and natural gravel specimens varies little with the strength grade of concrete, and the range is less than 10%.

Influence of coarse aggregate type on the bonding properties of steel tube specimens with different section shapes

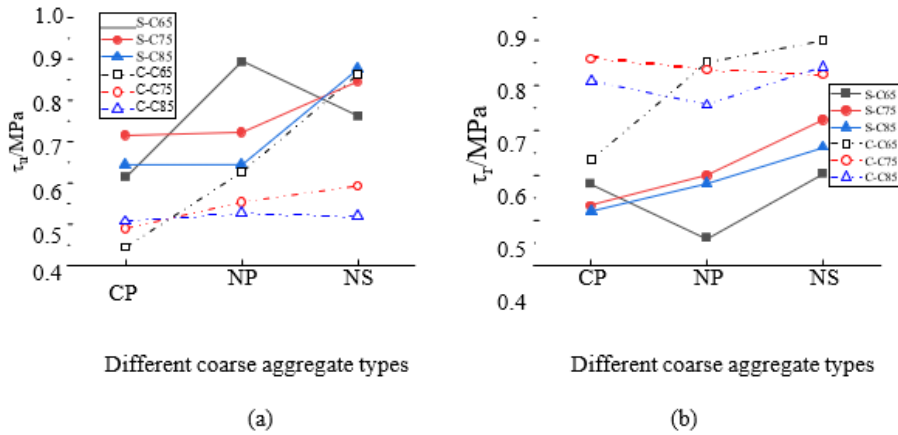


Figure 5: Comparison of bonding properties of steel tube specimens with different sections by coarse aggregate type

It can be seen from Figure (a) that the ultimate bond strength of square specimens is mostly higher than that of circle specimens for different coarse aggregate types. With the change of different coarse aggregate types, the limit bond strength of square and circle specimens is relatively discrete, and there is no obvious law to follow. It can be seen from Figure (b) that the residual bond strength of the circle specimen is higher than that of the square specimen for different coarse aggregate types. The residual bond strength of the square specimen generally increases with the change of the coarse aggregate using crushed pebble, natural pebble and natural stone, while the change of the circle specimen is more discrete and there is no obvious rule to follow.

CONCLUSION

For square specimens, the ultimate bond strength and residual bond strength of natural crushed stone specimens are the largest, and the ultimate bond strength and residual bond strength of crushed pebble specimens are the smallest. Whereas, for circle specimens, the ultimate bond strength of natural crushed stone specimens is the largest, and that of crushed pebble specimens is the smallest. Under the condition that the bond area is close to the same (the difference of the bond area of the specimens is less than 10%), the ultimate bond strength of the square specimen is mostly higher than that of the circle specimen, and the residual bond strength of the circle specimen is higher than that of the square specimen. For square and circle specimens, the ultimate bond strength and residual bond strength vary discretely with the concrete strength grade and coarse aggregate type.

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SUSTAINED LOAD AND AGING IMPACT ON WATERPROOF MEMBRANES: A REVIEW OF CURRENT RESEARCH

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ABSTRACT

Building leakage is a prominent quality issue today. The application of waterproof membranes is the most widespread in waterproofing projects, and these membranes must consider the influence of external and various natural factors, primarily including the effects of external forces, natural conditions, and defects in concrete structures. Only by accurately analyzing these influencing factors can scientifically grounded and operable repair solutions be proposed. This paper reviews relevant academic literature and reaches the following conclusions: (1) Studying the mechanical properties of waterproof membranes, such as tensile strength and elongation at break, under adverse or accelerated conditions is an intuitive and effective method for evaluating their performance. Under sustained loading and stress, the performance of waterproof membranes generally declines, including reduced waterproofing effectiveness and mechanical strength. (2) Although waterproof membranes demonstrate good durability, factors such as light, heat, and oxygen can still negatively impact their performance. Utilizing these factors to induce aging is a common method among researchers and is worth considering. (3) The results indicate that the durability of waterproof membranes is primarily determined by the base material. The impact of sustained loading under high-temperature conditions is more pronounced, potentially leading to accelerated material fatigue and aging. Despite the existence of numerous studies and review articles exploring various aspects of waterproofing, there remains a significant lack of in-depth reviews specifically addressing the impact of waterproof membranes under sustained loading and their aging performance. Given the increasing importance of concrete durability and water resistance in construction, it is crucial to systematically evaluate the performance of waterproof membranes. This research aims to fill this gap by examining the behavior of waterproof membranes under sustained loading conditions and assessing their effects on aging performance. Understanding these effects is vital for optimizing concrete performance and addressing long-term water resistance challenges. The necessity for this review lies in providing a comprehensive analysis of waterproof membranes, guiding researchers and engineers in selecting appropriate materials and techniques to enhance concrete protection.

Keywords:

Building Leakage, Waterproof Membranes, Mechanical Performance, Aging Performance, Temperature

INTRODUCTION

Building waterproofing engineering is an integral component of construction projects. Waterproofing technology in construction comprises specialized measures aimed at ensuring that the structures of buildings and structures are not compromised by water intrusion, and that interior spaces remain safeguarded from water-related hazards. This also refers to a series of structural, architectural, and construction measures taken to prevent the infiltration of water, including rainwater, industrial or domestic water, groundwater, stagnant water, capillary water, and water resulting from human activities, into the interiors of buildings and structures. These measures are also adopted to prevent leakage from water storage systems (Sun, D, 2016).

The primary purpose of architectural waterproofing is to safeguard the functionality of buildings, while also serving to extend the lifespan of the structures. Until the 1990s, China did not have specialized design standards for waterproofing engineering. During the design process, aspects such as roof waterproofing, drainage measurement, water downpipe diameter and quantity, insulation layer thickness, etc., were often determined based on experience or local customary practices. This frequently resulted in poor roof drainage and significant leakage issues (Ye, L, 2013).

Currently, there are many relevant standards, specifications, and regulations such as "Technical Code for Roof Engineering" (GB50345—2012), "Quality Acceptance Specification for Roof Engineering" (GB 50207—2012), "Technical Code for Waterproofing of Underground Engineering" (GB 50108-2008), and "Quality Acceptance Specification for Waterproofing of Underground Engineering" (GB 50208-2011) that provide a certain basis for the design and construction of building waterproofing projects. However, often due to insufficient experience of the designers, unfamiliarity with building waterproofing materials and construction practices, inadequate depth of waterproofing design, inability to guide construction or ineffective guidance, leakage issues may occur in building projects caused by the design. The technical level of building waterproofing projects urgently needs to be improved.

Waterproofing engineering involves three major aspects: preventing water from infiltrating the interiors of buildings, preventing water within water storage structures from leaking out, and providing mutual water resistance within buildings and structures. Building waterproofing engineering encompasses various components of buildings and structures, including basements, floors, walls, and roofs. Its primary function is to ensure that buildings or structures remain protected from erosion caused by different forms of water during their intended design lifespan (Zhu, Y., & Yuan, Y, 2021). This is achieved to guarantee that the architectural structure and interior spaces remain undamaged, providing people with a comfortable and secure environment. The requirements for waterproofing functionality differ based on the specific locations within the building, and the demands for waterproofing vary accordingly.

Waterproof membranes are flexible building materials that can be rolled up, primarily used for waterproofing in construction walls, roofs, tunnels, highways, landfills, and other areas. Their main function is to prevent the infiltration of external rainwater and underground water (Research Institute of Standard and Quota, 2022).

Waterproof membranes have a wide range of applications, including but not limited to waterproofing construction walls and roofs, as well as meeting waterproofing needs in tunnels, highways, basements, and other locations. As the first line of defence in engineering waterproofing, they are crucial for protecting building structures from moisture damage. Waterproof membranes, which were initially made from asphalt, have a long history. With advancements in technology, various types have emerged including polymer-modified asphalt membranes and synthetic polymer membranes.

At present, the usage of waterproofing materials in China's construction industry is steadily increasing. There is a continuous growth of new types of building waterproofing materials, primarily represented by modified bituminous waterproofing membranes which have taken a dominant position. The consumption of these new waterproofing materials accounts for 85.29% of the overall building waterproofing materials. Building waterproofing is still predominantly based on modified bituminous waterproofing membranes, accounting for over 60% of the total, with polymer waterproofing membranes making up 11.44%, and waterproof coatings comprising 13.07% (Liao, W, 2016). Among these, polymer waterproofing membranes have experienced rapid development over the past 20 years. They are characterized by high strength, significant elasticity and elongation, resistance to weathering and low temperatures, as well as simple construction, with PVC waterproofing membranes, in particular, being their representative (Xie, C, 2017).

During processing, storage, and utilization, polymer materials gradually deteriorate in performance due to the comprehensive effects of internal and external factors, ultimately resulting in the loss of their utility value. This phenomenon is referred to as "aging" (Eckhardt, H., & Schiller, M, 2005). Aging is an irreversible change, often characterized by irreversible chemical reactions. For instance, once "spots" appear on polyvinyl chloride film, these "spots" cannot be eliminated. The appearance of spots is a characteristic manifestation of aging in the visual aspect of polyvinyl chloride film.

Aging is a common problem for polymer materials, with almost no polymer material exempt from aging. Polymer material aging, akin to the weathering of rocks or the corrosion of steel bars, reflects a transition from quantitative to qualitative change under certain conditions. After monomers undergo polymerization or condensation to form polymers under specific conditions, aging occurs according to

certain laws due to internal and external factors. Some primarily degrade into low-molecular-weight polymers or other compounds, some revert to their original monomers, and some undergo cross-linking, ultimately leading to qualitative changes (Zhao, C., et al., 2012). Polymer material aging is an objective law beyond human will. It is impossible to absolutely prevent the aging of polymer materials. However, through the study of the aging process, one can gradually understand and master the regularities of polymer material aging (Kovacs, J. Z., & Yu, Y., 2016). By utilizing these regularities and implementing appropriate anti-aging measures, it is possible to slow down the aging process, enhance the material's resistance to aging, and thereby extend its service life.

The causes of polymer material aging can generally be attributed to two aspects: internal factors and external factors (Jiang, W., & Wu, D., 2018). Internal factors refer to the structural state of the basic components of polymer materials, which include the chemical and physical structures of polymers themselves, as well as the properties and proportions of various components within the polymer material system.

External factors refer to environmental factors outside the polymer material, including physical, chemical, and biological factors. These factors mainly include sunlight, oxygen, ozone, heat, moisture, mechanical stress, high-energy radiation, electricity, industrial gases (such as sulfur dioxide, ammonia, hydrogen chloride, etc.), seawater, salt spray, molds, bacteria, insects, etc. Among these external factors, sunlight, oxygen, and heat are particularly important causes of aging in various polymer materials. If sunlight, oxygen, and heat can be isolated, many polymer materials can remain stable for long periods without aging.

The raw material of waterproofing materials is polymer. Therefore, the essence of waterproofing material aging is essentially the aging reaction process of polymer. Polymers are exposed to natural environments during transportation and use. Under the influence of natural environmental factors such as sunlight, water, oxygen, and heat, they undergo "aging," which is the chemical degradation process of polymers (Kreilgaard, L. F., & Madsen, J. S. 2020).

When waterproofing membranes are used as roofing materials without protective layers, they undergo aging under the influence of light, heat, oxygen, etc., resulting in phenomena such as discoloration and cracking, leading to the failure of the waterproofing layer. Therefore, studying the aging durability of waterproof membranes is of significant importance for predicting the degree of degradation and service life of the waterproofing membranes. Experimental research is a common method for studying material properties. For example, Khir Johari et al. (2022), Che Mat et al. (2023), and Miasin and Chuan (2020) all employed this approach.

PROBLEM STATEMENT

Building leakage is a prominent quality issue at present, and the causes are diverse. Waterproofing projects must take into account the influence of external factors and various natural elements. Generally, the main considerations include the impact of external forces, the influence of natural conditions, and defects in concrete structures (Wang, Y., 2019). In other words, waterproofing membranes typically operate under complex factors such as loads, deformation, temperature, and exposure to ultraviolet radiation, and cannot be simply assessed based on a single factor.

In actual engineering practice, the most common cause of leakage is damage to the waterproofing membranes. Merely studying the performance of waterproofing membranes, themselves or qualitatively explaining the deterioration mechanism of the waterproofing membranes does not provide guidance for the construction of waterproofing membranes in real construction environments (Hu, J., & Qu, P., 2023).

Despite significant advancements in the development and application of waterproof membranes for concrete protection over the past few decades, there remains a critical gap in our comprehensive understanding of these membranes. Although numerous studies and review articles have explored various

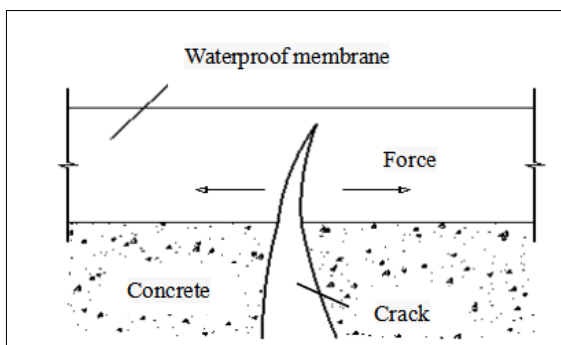
aspects of waterproofing, there is a notable absence of in-depth reviews specifically addressing the impact of waterproof membranes on sustained loading and their aging performance.

Given the increasing importance of concrete durability and water resistance in construction, it is essential to evaluate the performance of waterproof membranes systematically. This research aims to fill this gap by reviewing waterproof membranes in the context of sustained loading and assessing their effects on aging performance. Understanding these effects is crucial for optimizing concrete performance and addressing challenges associated with long-term water resistance.

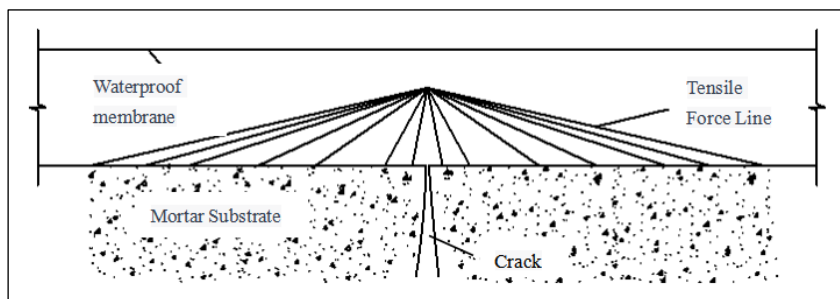
The need for this review arises from the necessity to provide a comprehensive analysis of waterproof membranes, which can guide researchers and engineers in selecting appropriate materials and techniques for enhanced concrete protection.

Mechanical Performance Analysis of Waterproofing Membranes

When the waterproofing membranes are fully adhered to the substrate, it is subjected to continuous stress due to deformation of the substrate, changes in environmental temperature, or loads on the waterproofing membranes. When cracks occur in the substrate, because the waterproofing membranes on both sides of the crack are firmly bonded to the substrate and the crack width is usually small, the change in crack width will have two effects on the waterproofing membranes at the crack site as shown in Figure 1(a) & (b) (Wang, T., 1997):



- (a) The strain generated by the waterproofing membranes at the crack site is much greater than that of the waterproofing membranes on both sides of the crack (Wang, T., 1998)



- (b) The waterproofing membranes at the crack site are subjected to additional load after sustained loading.

Figure 1: Change in crack effects on the waterproofing membranes (Wang, T., 1998)

As a result, the waterproofing membranes at the crack site are more prone to failure. Its performance evaluation should take into account the influence of sustained loading, especially the tensile properties of the material after sustained loading.

Zhang, S. et al. (2022) conducted mechanical performance experiments and analyzed the microscopic failure mechanisms of internally reinforced thermoplastic polyolefin (TPO), homogeneous ethylene propylene diene monomer (EPDM) waterproof membranes, and related supporting materials for pressure-sensitive, self-sulfurized expansion joints. Xie Xiong and other scholars used polyethylene-polypropylene composite waterproof membranes as the research object, conducted aging tests, and accelerated aging through artificial corrosion methods. They investigated the influence of aging on mechanical properties such as fracture strength and elongation at break through tensile tests. Zhang, G. et al. (2022) also studied three types of homogeneous TPO waterproof membranes and investigated the effects of thermal aging temperature and time on their tensile strength, elongation at break, tear strength, mass loss, and melt mass flow rate.

This indicates that studying the mechanical properties of waterproof membranes, such as tensile strength and elongation at break, under adverse or accelerated conditions is a very intuitive and effective way to evaluate the performance of waterproof membranes.

Han, Q. et al. (2019) pre-applied a 100% strain to materials and investigated the aging performance of thermoplastic polyolefin (TPO) membranes and polyvinyl chloride (PVC) membranes in different environments. This was done to reflect the durability of waterproof materials under stress (strain) conditions. Their research found that under 100% strain, PVC membranes were prone to notch fracture in strain environments. Compared to PVC membranes, TPO membranes exhibited superior resistance to heat aging and boil aging.

Figure 3.2 shows the mechanical performance test results of TPO and PVC membrane specimens before and after 7 days of thermal treatment at 115°C under 100% strain. As illustrated in Figure 2, the tensile strength at break of the PVC membrane specimens was 0 (specimens failed prematurely) after 7 days of thermal aging at 115°C under 100% strain, whereas the tensile strength at break of the TPO membrane specimens also showed a significant decrease following thermal aging treatment.

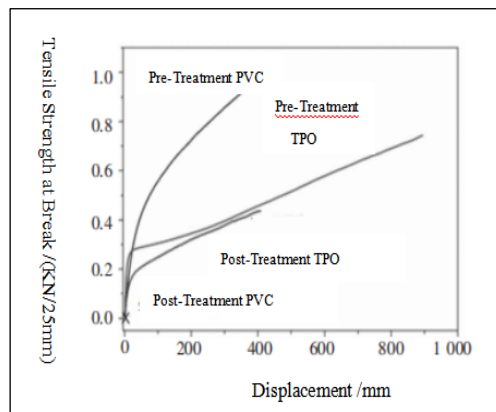


Figure 2: Mechanical Performance of Specimens Before and After Thermal Aging Under 100% Strain

Wang, X. et al. (2020) found that the performance of waterproof membranes significantly deteriorates under sustained loading, especially at high temperatures. Long-term loading leads to material fatigue and stress concentration, which in turn reduces their waterproofing effectiveness and mechanical strength. Chen, L. et al. (2019) showed that waterproof membranes exhibit different stress-strain

behaviors under various stress conditions. Sustained loading causes plastic deformation and performance degradation of the material, while proper load management can significantly improve long-term stability.

Zhang, Y. et al. (2018) found that polymer-modified waterproof membranes exhibit better durability under long-term stress. However, excessive loading can lead to an increase in microcracks within the material, affecting its overall waterproofing performance. While Yang, H. et al. (2017) discovered that sustained loading significantly impacts the mechanical properties and waterproofing performance of membranes. Stress concentration points under prolonged loading can lead to a severe decline in waterproofing performance. Huang, X. et al. (2016) indicated that mechanical stress has a significant effect on the long-term performance of waterproof membranes. Stress concentration and sustained mechanical loading accelerate the aging process of the material and reduce its waterproofing effectiveness.

The studies mentioned above indicate that waterproof membranes generally experience performance degradation under sustained loading and stress, including a reduction in waterproofing effectiveness and mechanical strength. The impact of sustained loading is more pronounced under high-temperature conditions, potentially leading to accelerated material fatigue and aging. Polymer-modified waterproof membranes exhibit better durability, but long-term loading still negatively affects their performance. Stress concentration and prolonged mechanical loading may lead to the formation of microcracks, thereby affecting the waterproofing performance. Sustained loading or a certain level of strain is detrimental to waterproof membranes.

Aging Performance of Waterproofing Membranes

When waterproofing membranes are used as roofing materials without protective layers, they undergo aging under the influence of light, heat, oxygen, etc., resulting in phenomena such as discoloration and cracking, leading to the failure of the waterproofing membranes. Therefore, studying the aging durability of waterproof membranes is of significant importance for predicting the degree of degradation and service life of the waterproofing membranes.

Ge, Y. et al. (2020) conducted a study on Styrene-Butadiene-Styrene (SBS modified asphalt waterproof membranes used in waterproofing projects for 12 and 20 years. They found that although the performance of SBS modified asphalt waterproof membranes had deteriorated to varying degrees, they still maintained good waterproofing capabilities and did not reach the failure standard of waterproof membranes. Zhang, G. et al. (2007) conducted natural exposure aging and immersion treatments on SBS modified asphalt waterproof membranes and rubber powder modified asphalt waterproof membranes. The results showed that the durability of SBS modified asphalt waterproof membranes was significantly better than that of rubber powder modified asphalt waterproof membranes.

Ge, B. et al. (2017) studied the various properties of SBS modified asphalt waterproof membranes of the same specification produced by different manufacturers after natural aging. They found that under natural exposure conditions, the polyethylene (PE) film on the surface of the waterproof membrane gradually disappeared, and the asphalt coating layer gradually hardened, became powdery, and developed cracks. Although natural exposure aging tests provide more realistic and credible data, they have long test cycles, complex environments, and many variables. It is also difficult to conduct single-factor studies in such tests. In order to improve testing efficiency, artificial accelerated aging methods are often used.

Ge, Y. et al. (2020) studied the durability of SBS modified asphalt waterproof membranes and found that the effects of UV aging and xenon lamp aging were similar. The aging efficiency of these two methods was greater than that of thermal aging at 70°C. Zhu, M. et al. (2017) studied the influence of organic montmorillonite on the anti-UV aging performance of asphalt using infrared spectroscopy. They found that the combination of organic montmorillonite and SBS improved the anti-UV aging performance of SBS-modified asphalt waterproof membranes.

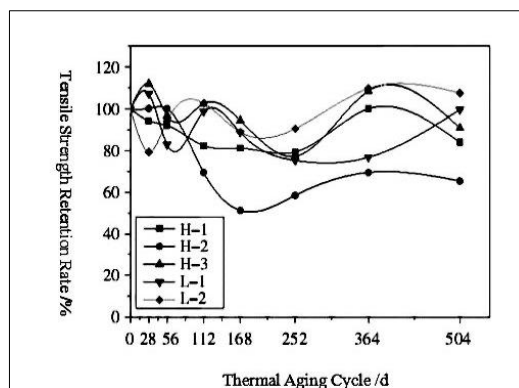
Che, J. et al. (2006) conducted durability studies on SBS modified asphalt waterproof membranes using xenon lamp aging and immersion experiments. The results showed that SBS modified asphalt waterproof membranes with polyester felt and alkali-free glass fibre felt as the substrate had better water resistance compared to those with polyester non-woven fabric and high-alkali glass fibre mesh fabric as the substrate. Wei, G. et al. (2018) compared the performance of SBS modified asphalt waterproof membranes and polyester glass fibre fabric asphalt membranes under different conditions of UV heating aging. They found that the aging resistance of the polyester glass fibre fabric asphalt membranes was superior

Kováč, J. et al. (2022) deal with the laboratory testing of a waterproofing membrane based on PVC-P in terms of its degradation from UV radiation, humidity, and temperature. They found that the experimental measurements point to a qualitative diversity of materials, and degradation takes place on both sides of the surfaces. Degradation due to the temperature also occurs on the side that is not exposed to UV radiation

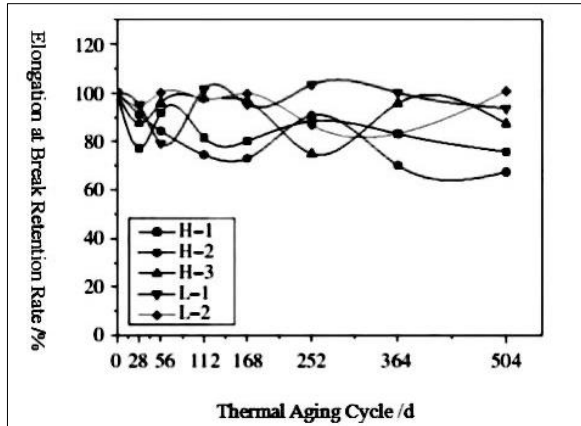
In a study by Li, Q. et al. (2022), the aging performance of high viscosity modified asphalt was evaluated based on the simulated heat-light-water coupled conditions, in which different aging effects and degrees were considered. They found that the coupled aging effects should be considered during the service period since acid rain solution and UV light also led to significant influences on the viscoelastic properties, high and low-temperature performance, and fatigue performance as similar to high temperature.

Zagorodnikova, M. A. et al. (2019) examined physical and mechanical properties taking into account the influence of typical aggressive impacts and evaluation of the durability of PVC membranes used as roofing materials. They found that the structure of the material and the effect of external factors had a direct effect on the thermal extension of PVC membrane samples. They also found that the waterproof film developed by the combination of polyurethane (PU) and industrial grade asphalt has excellent performance. It mainly has a high elongation range and has the allowable requirements of tensile strength, tear value, puncture resistance and shore hardness specified in the corresponding ASTM specification. Xiong, Y. et al. (2023) subjected five types of polymer self-adhesive waterproof membranes and their bonding with cast-in-place concrete to thermal aging treatment. They then conducted durability-related performance tests at different observation time points.

Tensile performance tests were conducted on the polymer self-adhesive waterproof membrane specimens under various thermal aging cycles, with the results shown in Figure 3. As seen in the figure, during the 90°C thermal aging test, the tensile strength and elongation at break of the five types of polymer self-adhesive waterproof membranes mainly exhibited fluctuations over 364 days. A decay trend only became apparent after continuing aging for 504 days, with the rate of decay in elongation at break being greater than that of tensile strength (Xiong, Y., et al., 2023)



(a) Tensile Strength Retention Rate of Membranes Under Different Thermal Aging Cycles



(b) Elongation at Break Retention Rate of Membranes Under Different Thermal Aging Cycles

Figure 3: Tensile Properties of Membranes Under Different Aging Cycles (Xiong, Y., et al., 2023)

The results indicate that the durability of the membrane itself is primarily determined by the base material. Tensile strength and elongation at break are the most commonly used evaluation parameters for plastic aging.

Ge, Y. et al. (2020) studied the aging rates of three artificial accelerated aging methods: UV aging, xenon arc aging, and thermal aging. The results are shown in Figure 4. For SBS-modified asphalt membranes, the actual aging effects of xenon arc aging and UV aging are similar, with both aging rates being higher than that of thermal aging at 70°C.

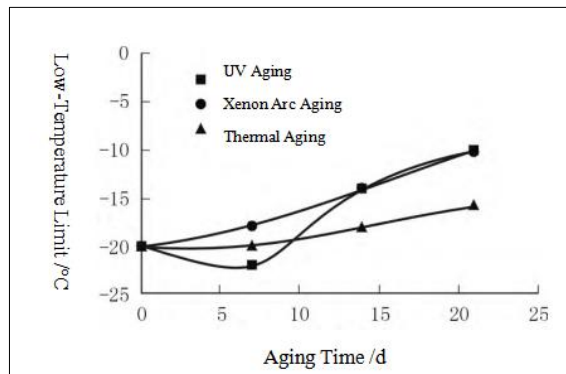


Figure 4: Comparison of Aging Rates for Three Types of Artificial Accelerated Aging Methods (Ge, Y., et al., 2020)

It is found that in natural exposure aging as well as artificial accelerated aging, the method of using factors like light, heat, and oxygen to induce aging is commonly employed by researchers and is worth considering. The aging effects of xenon arc aging and UV aging are superior to those of thermal aging at 70°C.

In summary, the literature indicates that many scholars have used factors such as light, heat, and oxygen to induce accelerated or natural aging in their studies of the mechanical and aging performance of waterproof membranes. The advantage of this method is that it provides a thorough investigation of the material properties of waterproof membranes. However, it also has a drawback: it neglects the actual

working conditions of the waterproof membranes, which are primarily subjected to sustained loading or a certain level of strain for most of the time.

CONCLUSION

Based on the summary of the above research, the following conclusions can be drawn:

(1) Studying the mechanical properties of waterproof membranes, such as tensile strength and elongation at break, under adverse or accelerated conditions is a highly intuitive and effective method for evaluating their performance. Under sustained loading and stress, waterproof membranes generally exhibit a decline in performance, including reduced waterproofing effectiveness and mechanical strength.

(2) While waterproof membranes demonstrate good durability, factors such as light, heat, and oxygen still negatively impact their performance. The use of these factors to induce aging is a common method among researchers and is worth considering.

(3) The results indicate that the durability of the membrane is primarily determined by the base material. The impact of sustained loading under high-temperature conditions is more pronounced, potentially leading to accelerated material fatigue and aging.

Waterproof membranes are widely used waterproof materials in building waterproofing projects. The influence of external and various natural factors on waterproof membranes must be considered. Only by accurately analyzing these influencing factors can scientifically grounded and operable repair solutions be proposed.

By integrating the research factors and methodologies of various scholars, studying the effects of sustained loads or stress under conditions of light, oxygen, heat, and others on the mechanical properties and aging performance of waterproof membranes can systematically evaluate their performance. Additionally, by examining the behavior of waterproof membranes under sustained loading conditions, we can assess their impact on aging performance. Understanding these effects is crucial for optimizing concrete performance and addressing long-term water resistance challenges.

Through a comprehensive analysis of waterproof membranes, this research aims to guide researchers and engineers in selecting appropriate materials and techniques to enhance concrete protection.

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THE LIFE OF RIGHTS LIES IN THE STRUGGLE: A JURISPRUDENTIAL ANALYSIS OF JHERING'S THOUGHTS ON THE STRUGGLE FOR RIGHTS

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ABSTRACT

Rudolf von Jhering's *The Struggle for Rights* proposes a dynamic concept of rights realization, challenging the traditional static view of rights and emphasizing the necessity for individuals to defend their rights through struggle. This idea not only reveals that the vitality of rights comes from struggle, but also delves into its legal basis and ethical value. Jhering believes that the struggle for rights is not only a legal act, but also a moral obligation, through which individuals not only achieve self-protection, but also promote the progress of the rule of law and the realization of justice in society. At the same time, his theory of legal feelings further deepened the moral basis of the struggle for power, emphasizing the combination of emotions and the rule of law. In modern society, the struggle for rights must not only rely on the positive actions of individuals, but also need to be integrated with the legal system to achieve more effective rights protection and social justice. Although Jhering's theory of struggle faces many challenges in the application of modern society, such as over-reliance on individual struggle and neglect of institutional guarantees, his ideas still have important practical significance in cultivating the awareness of civil rights and building a society under the rule of law. Through a philosophical conceptual discourse, the duality of rights struggles, the dynamic balance between the individual and society, and rights and justice are critically explored. Undeniably, Jhering's theory provides us with a unique perspective to understand the coordinated development of individual rights and social justice in a modern society governed by the rule of law.

Keywords:

Rights-based thinking, "The Struggle for Rights", Legal feelings, Jhering, Social justice

INTRODUCTION

In the long history of law, the nature and realization of rights have always been one of the core topics in legal theory and practice. Caspar Rudolph Ritter von Jhering, one of the most influential German jurists of the 19th century, undoubtedly offered a revolutionary perspective on the understanding and interpretation of rights in his book *Der Kampf ums Recht (The Struggle for Law)* (1872; reprint 2018). Jhering's idea that "the life of rights lies in struggle" in his book reveals that rights are not static and fixed legal concepts, but can only be established and maintained through the continuous struggle of individuals. Through this theory, Jhering challenged the traditional concept of rights and emphasized the legal and ethical basis of the struggle for rights, which made his thought have an important position and influence in both legal theory and modern rule of law practice.

As one of the famous representatives of the German school of historical law, Jhering's academic achievements are not limited to the study of Roman law, but also include a deep insight into modern legal theory. His ideas of rights have had a profound impact on the construction of the entire legal system. In his book, Jhering vividly and passionately reveals that rights are not a passively accepted legal arrangement, but need to be acquired and guaranteed through sustained efforts and struggles. He pointed out that the essence of rights lies in struggle, and struggle is the source of its vitality. In the development of jurisprudence in the 19th century, Jhering's thought became an important turning point. He emphasizes the balance between rights and duties, and explores the interaction between individual rights and social order through an in-depth analysis of rights struggles. His doctrine has directly influenced the ideological system of many jurists in later generations, especially in the cultivation of civil rights, the construction of the rule of law, and the realization of social justice (Wang Fuxing & Liao Xian, 2011:71)

The core ideas of the book, are epitomized by Jhering's dynamic understanding of rights. In traditional legal theory, rights are often regarded as static results conferred by law, and once established, they are considered to have legal force and enforceability. However, Jhering breaks through this notion by proposing that rights are not automatic entities, but survive and develop through the struggle of individual social beings. In the book, he emphasizes that the existence of rights not only depends on the written provisions of the law, but also requires individuals to take active actions in the face of rights infringement to fight and defend their rights. (Zhang Lei, 2016:303).

Jhering's theory of the essence of rights starts from the acquisition and realization of individual rights, and puts forward the idea of "rights are struggles". In his book, Jhering not only emphasizes the relationship between rights and struggles, but also introduces the concept of "legal feelings" (Rechtsgefühl) to further illustrate the ethical basis of rights struggles. Exploring Jhering's idea of rights struggle is of great significance for understanding the rights protection mechanism in a modern society governed by the rule of law.

ANALYSIS OF JHERING'S "STRUGGLE" THOUGHT

Jhering's idea of "struggle for rights" has a high influence in the legal community, and his unique insights not only profoundly reveal the essence of rights, but also provide us with a new perspective to understand the process of realizing rights. By exploring the centrality of "struggle" in rights, Jhering emphasizes the inseparability of rights and struggles, as well as the ethics and legal rationality of rights struggles. This ideological framework not only redefines the connotation of rights, but also endows "legal feelings" with an important role in the realization of rights.

a. The theoretical framework of Jhering's thought on the struggle for rights

(i) The inseparability of rights and struggles

In Jhering's ideology, the life of rights is inseparable from struggle. Unlike traditional jurists, Jhering does not view rights as a static legal protection or fixed institutional arrangement, but rather emphasizes the dynamic nature of rights, arguing that they need to be established and developed through struggle. Struggle is not only a source of rights, but also a necessary condition for the continuation of rights. In other words, rights do not exist through the unilateral granting of law, but are realized through the continuous fighting, protection and maintenance of individuals and groups in society (Wang Fuxing & Liao Xian, 2011:811).

Jhering's idea of the struggle for power is rooted in a deep insight into social reality. He recognized that the law alone was not sufficient to fully guarantee rights, and that its effectiveness needed to be maintained by the actual forces in society. In this process, struggle has become the central factor: only through the process of continuous struggle can rights be transformed from legal provisions into real social forces, and can be recognized and enforced by society (Zhang Lei, 2016:302).

This inseparability of rights and struggles has multiple meanings in Jhering's thought. First of all, rights are not given by nature, but are gradually acquired through conflicts and struggles in history. Rights are not only the object of legal protection, but also part of the self-realization of the individual. Second, Jhering emphasized that the struggle is not only a fight for individual rights, but also a contribution to the realization of social justice and the legal order. Through the struggle, individual rights were upheld, and the legal system of society as a whole was constantly improved. This makes Jhering's idea of the struggle for rights strongly realistic and practical.

Jhering's theory of struggle breaks with the traditional understanding of rights as a passively accepted legal concept, and instead sees rights as an active social phenomenon that needs to be fought for through action and will. This thought of his not only influenced later generations of

legal researchers, but also provided an important theoretical basis for the cultivation of civil rights awareness. In a modern society governed by the rule of law, Jhering's theory of the struggle for rights provides insight into how rights are established and guaranteed in the legal system.

(ii) The ethics and legal rationality of rights

Jhering's idea of the struggle for rights is not only at the level of legal theory, but also involves the ethical basis of rights. He believes that rights are not only legal rights, but also have profound ethical and moral connotations. Rights are not only related to the legal interests of individuals, but also to the dignity and personality of individuals and the realization of social justice. In Jhering's view, the struggle for rights is not only a legal act, but also a moral responsibility and obligation. This means that rights need not only to be guaranteed by law, but also to be fought by individuals to defend their dignity and personality (Du Ruyi, 2018:176).

Jhering emphasized that the struggle to renounce rights is not only a compromise of the law, but also a betrayal of the dignity of the individual. He believes that if an individual chooses to give in or give up the struggle in the face of rights infringement, it not only damages his own rights, but also ethically deviates from his own dignity and personality. This view closely links the realization of rights with moral responsibility, making the struggle for rights not only part of legal action, but also part of moral action. Through struggle, individuals can not only safeguard their legitimate rights and interests, but also achieve self-affirmation and self-protection in ethics.

Jhering's theory not only emphasizes the ethics of rights, but also reveals the deep connection between rights and duties. The realization of rights not only means that individuals enjoy some kind of legal protection, but also means that individuals have the obligation to actively fight for and defend their rights. Through struggle, individuals are able to achieve self-realization, both legally and ethically. This view breaks the opposition between rights and duties in traditional jurisprudence and emphasizes their unity in the process of struggle. Jhering's ideas on the struggle for rights offer a new perspective on the jurisprudential basis of rights. By combining rights and struggles, ethics and jurisprudence, he reveals that the realization of rights is not only a legal arrangement, but also the result of an individual's active participation in social life and legal practice. This idea has important practical significance in the modern society of the rule of law, especially when the rights of individuals are violated, and Jhering's theory of struggle provides effective legal and ethical guidance for individuals.

b. The connotation of Jhering's thought on rights and the concept of legal feelings

(i) The moral basis of rights

Jhering's idea of rights has a deep moral foundation. He believes that rights are not only a tool given to individuals by law, but also a manifestation of individual dignity and personality. In other words, rights are not only about legal interests, but also about the moral existence and social values of individuals. Jhering's idea is fully demonstrated through the theory of the "struggle for power". He believes that in the process of fighting for rights, individuals are not only protecting their own interests, but also defending their dignity and personality. Jhering particularly emphasized that the realization of rights does not depend only on the protection of the law, but also requires the active struggle of individuals. The right without struggle is a false right and has no vitality. The realization of rights needs to be accomplished through the moral feelings of the individual and the legal action of the individual. As he put it: "Those who have not experienced the pain of having their rights violated cannot truly understand the meaning of rights." This kind of thinking makes rights not only a concept in the text of the law, but also closely linked to profound ethical values such as personal dignity and social justice (Zhang Lufang, 2017:128).

The moral basis of rights has a dual meaning in Jhering's system of thought. On the one hand, it links rights with the moral values of individuals, making the realization of rights part of the

individual's self-realization. On the other hand, it connects the individual with the moral order of society through struggle, and promotes the process of rule of law in the whole society. Therefore, the struggle for rights is not only a legal act, but also an important means for individuals to achieve social justice through their actions.

(ii) The connection between legal feelings and the struggle for rights

In Jhering's thought on rights, "legal feelings" as a core concept further deepens the relationship between rights and struggle. Legal feelings refer to the moral feelings and sense of justice that individuals have in the face of rights violations. Jhering believes that legal feelings are an important internal motivation for individuals to take action and fight for their rights. The legal feeling is not only an emotional response, it is also the moral basis for the individual to defend his rights. In Jhering's view, the realization of rights depends not only on the protection of the legal system, but also on the individual's emotional identification with the rights and the sense of moral responsibility. When individuals feel that their rights have been violated, legal feelings motivate them to take action and defend their rights through struggle. This emotion plays a crucial role in Jhering's theory, as it provides individuals with the moral legitimacy and motivation to fight for their rights (Liu Dandan, 2015:5).

The theory of legal feelings not only explains why individuals are willing to fight for rights, but also reveals the ethical value of rights struggles. Through legal feelings, Jhering pointed out that the struggle for rights is not only a legal act, but also a kind of moral self-protection. By defending their rights, individuals protect their moral dignity and contribute to social justice and the stability of the law. From the perspective of jurisprudence, the concept of legal sentiment enriches the way in which rights are realized. Jhering's theory breaks through the limitations of traditional jurisprudence that separates law and morality, combines individual moral feelings with legal behavior, and emphasizes that law is not just a cold article, but a social practice full of vitality. Through legal feelings, individuals are not only passive recipients of rights in the legal system, but also active defenders and practitioners of rights.

Jhering's idea of the struggle for rights provides a new perspective for modern jurisprudence, emphasizing that the realization of rights depends not only on the guarantee of the legal system, but also on the active struggle of the individual and the promotion of legal feelings. By revealing the inseparable link between rights and struggle, Jhering not only gives life to rights, but also provides them with an ethical basis. The realization of rights is not only a legal issue, but also a manifestation of individual human dignity and social justice. In modern society, Jhering's thought has important guiding significance for the cultivation of citizens' rights awareness, the construction of the rule of law and the realization of social justice (Yuan Peng, 2014:296).

THE LIFE OF THE RIGHT LIES IN THE CONTEMPLATION OF STRUGGLE

By systematically expounding the legal basis of the rights struggle, Jhering profoundly reveals the duality of the rights struggle, that is, the complex interaction between individual rights and social order. He pointed out that rights are not only a legal outcome, but also a dynamic process that needs to be acquired and maintained by individuals through struggle. At the same time, Jhering's theory also reveals the ethical basis and legal legitimacy of the power struggle, showing that giving up rights is not only a legal defeat, but also a betrayal of one's own human dignity.

a. The duality of the struggle for power – the interaction between the individual and society

(i) Reconciliation of individual rights with social order

Jhering's idea of rights struggle is based on the interaction between individual rights and social order, emphasizing that the realization of individual rights is not an isolated act, but is carried out on the basis of dynamic balance with social order. In his theoretical framework, the protection of individual rights is not only a way for individuals to realize their self-worth, but also a support and promotion for the rule of law and order of the whole society. He believes that in the process of asserting their rights, individuals are actually maintaining and strengthening the overall justice and order of society. There is an interdependent relationship between the realization of individual rights and the social order. Through the duality of the struggle for power, he reveals the harmonious coexistence of individual rights and social order. By defending their rights, individuals not only protect their own interests, but also promote the stability and development of social order. The occurrence of rights struggle is the reaction of individuals against the infringement of rights, but this reaction not only promotes the improvement of social justice and the rule of law, but also ensures the realization of individual dignity and freedom (Li Yayue, 2011: 32).

Jhering's view breaks the binary opposition between individual rights and social order in traditional jurisprudence. He believes that the realization of individual rights must depend on the overall social order, and the stability and progress of social order also depend on each individual's active struggle for rights. When individuals pursue their rights, they are actually pushing society in a more just and reasonable direction. Struggle is not only a means for the realization of individual rights, but also a driving force for the development of social justice and order. This dynamic equilibrium of power and order is at the heart of Jhering's theory.

(ii) Rights serve as a bridge between the individual and society

In Jhering's theory, the struggle for rights is not only the defense of individual rights, but also the bridge between the individual and society. Through the struggle for rights, individuals link private interests with public interests, thereby promoting the development of the rule of law in society. Jhering believes that the realization of rights is not only about the interests of individuals themselves, but also about the justice and stability of the whole society. The struggle for rights is not only a tool to guarantee individual freedom, but also a source of power for the progress of society as a whole. Through power struggles, individuals constantly challenge the existing social order, so that the legal system is constantly improving and evolving in the process of responding to these challenges. Individual rights needs and fighting behaviors promote the adaptability and flexibility of the legal system, thereby promoting the development of the rule of law. Jhering's thought reveals how the struggle for rights can promote the soundness and perfection of the social rule of law system while safeguarding individual interests (Zhu Xiaozhe, 2008: 20).

In Jhering's theory, individual rights are not just a static concept conferred by law, but a dynamic process that needs to be consolidated and developed through struggle. Through the struggle for rights, individuals not only defend their legitimate rights and interests, but also make the legal system more adaptable to the changes and needs of society through this behavior. Jhering believes

that the struggle for rights is an important force to promote the construction of the rule of law in society, because every claim and maintenance of rights will promote the adjustment and evolution of the legal system, so as to achieve a higher level of social justice.

This bridging effect between rights and society is especially reflected in the cultivation of citizens' awareness of rights. Jhering emphasized that citizens defending their rights through struggle not only enhance their awareness of the rule of law, but also promote the construction of a culture of rule of law in society as a whole. In modern society, the awakening of citizens' rights awareness is essential to promote the construction of the rule of law and maintain social order. Through the struggle for rights, individuals not only safeguard their own legitimate rights and interests, but also contribute to the rule of law and order of the whole society (Zhang Lei, 2016: 302).

THE ETHICAL BASIS AND LEGAL LEGITIMACY OF THE STRUGGLE FOR RIGHTS

(i) The ethical consequences of giving up rights

The theory of the struggle for rights not only has a legal dimension of legitimacy, but also contains a profound ethical foundation. In his view, an individual who gives up his rights is in fact betraying his human dignity and social responsibility. The struggle for rights is not only a legal act, but also a moral obligation. Through this view, Jhering emphasises the ethical responsibility of individuals to defend their rights. In Jhering's view, giving up one's rights means denying one's own human dignity, which is a kind of 'spiritual suicide'. Individuals who choose to tolerate and give up their rights in the face of infringement will not only lose their legal protection, but also suffer from self-degrading on the moral level. Through this viewpoint, Jhering reveals the ethical basis of the struggle for rights, that is, the individual must defend his dignity and value through the struggle, the struggle for rights is not only the resistance to the external infringement, but also the affirmation and defence of self-personality.

The realization of rights is not only the result of the law, but also depends on the struggle and action of the individual. If an individual does not take the initiative to defend his own rights, then even if the law gives him the corresponding rights, these rights will gradually lose their significance. Abandonment of rights not only means the loss of individual rights and interests, but also means the rejection of social justice. In Jhering's theory, the struggle for rights is a kind of moral obligation, and by defending their rights through struggle, individuals are also defending social justice and order. This idea has important practical significance in modern society. The realization of rights is not only about the guarantee of law, but also about the individual's defence of his own personality and moral responsibility. Jhering's thought reminds us that rights are not only an externally given legal guarantee, but also an internal moral responsibility. Individuals uphold their dignity and value by defending their rights, an act that is not only beneficial to the individual but also has a positive impact on the justice and moral order of society as a whole.

(ii) The realization of legal feelings and rights

In Jhering's idea of the struggle for rights, the concept of 'legal feelings' plays an important role. Legal feeling refers to the sense of justice and moral responsibility generated by individuals in the face of infringement of rights, and it is the internal motivation that pushes individuals to take action to defend their rights. According to Jhering, the struggle for rights is not only a legal act, but also a moral obligation, and legal feelings play a crucial role in this process. The theory of legal feelings reveals that the law is not only a cold institutional system, but also contains the individual's emotions and moral aspirations. Legal feelings not only promote the individual's struggle for rights, but also provide moral justification for the struggle for rights. Individuals

recognize that their rights are being violated through legal feelings and defend them through struggle. This struggle is not only an act of legal self-protection, but also moral self-realization.

Legal feelings make law a dynamic practical process rather than a rigid system of rules. Through the struggle for rights, individuals not only defend their rights and interests, but also promote the progress and development of society. Jhering's theory of legal feelings provides important theoretical support for the rights protection mechanism in modern rule of law society, emphasizing that law is not only the existence of the institutional level, but also the embodiment of emotions and morality

(iii) The social effect of the struggle for rights and its promotion to the rule of law

The struggle for rights is not only related to the legitimate interests of individuals but also has a profound impact on the overall development of society. Jhering emphasizes that the struggle for rights is a significant force driving social change. Many major social advancements and legal reforms throughout history have been achieved through such struggles. Through both individual and collective efforts, injustices within society can be exposed and rectified, leading to the improvement and consolidation of social order. The social effects of the struggle for rights are evident not only in the enhancement of the legal system but also in the protection of public interests. (Du Ruyi, 2018: 182). By advocating for their rights, individuals contribute to the realization of social justice and safeguard the common good. Jhering posits that the struggle for rights is not merely a result of individual actions but also a driving force for societal progress. Through these struggles, individuals not only defend their own rights but also promote social change and the protection of public interests.

Jhering's ideas on the struggle for rights are of profound revelation to the construction of the rule of law. He pointed out that the struggle for rights is an important force in promoting the continuous improvement of the legal system. Every claim and struggle for rights will trigger the adjustment and progress of the legal system. In this process, the law is not only a tool for individuals to defend their rights, but also a means to achieve social order and justice. As can be seen through actual cases, many major legal changes have been realized through rights struggles. Whether it is workers fighting for labour rights or disadvantaged groups fighting for equal rights and interests, the struggle for rights is an important driving force for the reform of the legal system. Jhering's thought reveals the central role of the rights struggle in the construction of the rule of law, pointing out that the realization of rights depends not only on the enactment and implementation of laws, but also on the active participation and struggle of individuals. The theory of rights struggle has also had an important impact on modern civic education. He believes that the cultivation of civil rights awareness is the basis for promoting the construction of a society based on the rule of law. Through the rights struggle, individuals not only safeguard their legitimate rights and interests, but also contribute to social justice and the construction of the rule of law. Therefore, Jhering's thought provides a theoretical basis for modern civic education, especially in the cultivation of citizens' awareness of rights and the concept of the rule of law is of great guiding significance.

Jhering's idea of the struggle for rights reveals the duality of the realization of rights: it is not only the process of defending individual rights, but also an important driving force for promoting social justice and the construction of the rule of law. The struggle for rights not only has legal legitimacy, but also has a profound ethical foundation. Through the struggle for rights, individuals not only achieve self-protection, but also make important contributions to social progress and the protection of public interests (Zhang Lei, 2016:306).

CRITICAL THINKING AND QUESTIONING

The idea of struggle for rights is a challenge to the traditional static concept of rights, emphasizing the necessity for individuals to realize and defend their rights through struggle. However, Jhering's struggle theory also has some limitations and idealistic tendencies, especially in the complex context of modern rule of law society, and its applicability and practicability deserve further discussion. This part will critically consider and question Jhering's theory in terms of the limitations of rights struggles and legal sentiments, the legal system and rights safeguards, and the practical dilemmas of rights struggles.

a. *The struggle for rights and the limitations of legal feelings*

(i) *The potential problem of over-reliance on individual rights*

Jhering's theory of the struggle for rights attaches great importance to individual initiative, emphasizing that individuals should actively struggle in the face of rights violations in order to safeguard their legitimate rights and interests. This theory is attractive in its ethical and legal dimensions, especially in encouraging the awakening of civil rights consciousness and the defence of social justice. However, Jhering relies too much on the way individual rights are defended and ignores the importance of institutional safeguards in a modern society governed by the rule of law. The development of the rule of law in modern societies relies on the soundness of the legal system and the effective functioning of the judicial mechanism, rather than relying solely on individual struggles for rights. In highly institutionalized rule of law countries, the legal system has gradually developed into a self-adjusting and perfecting mechanism, and through the joint role of legislation, justice, law enforcement and other parties, the realization of legal rights relies more on the safeguard of the system itself than on the individual's struggling behaviour. Although Jhering's theory highlights the individual's subjective initiative, it overlooks the central role of the legal system in the protection of rights, resulting in his theory of struggle being overly idealized in the complex legal context of modern times.

(ii) *Limitations of the theory of juridical feelings*

Jhering's theory of legal feelings attempts to drive the struggle for rights through an individual's emotional identity and sense of morality, emphasizing an individual's moral obligation and sense of justice in the face of rights violations. Although this theory plays an important role in inspiring individuals to fight for their rights and evoking a sense of justice in society, its application faces many difficulties in modern legal practice.

Modern legal practice relies on clear legal norms and procedures, and the implementation of law is usually carried out through institutionalized procedures and objective standards, rather than relying on individual emotions or moral feelings. While Jhering's theory of legal feelings can provide moral impetus to the struggle for rights, its practical application may conflict with the modern legal system's focus on objectivity, procedure, and norms. In a society that emphasizes legal rationality and procedural justice, legal feeling may not be able to exist independently of the system. It needs to rely on the support and guidance of the system in order to avoid the conflict between the subjectivity of emotion and the objectivity of law.

Another limitation of legal sentiment is that it may not be able to adequately cope with the complexity of legal relations in modern society. With socioeconomic development, the problem of rights infringement has become increasingly complex and the subjects of interest involved are diversified. Simply relying on individual emotion and moral sense to promote the struggle for rights may not be able to adapt to this complex social reality. Jhering's theory of legal feelings is too idealistic and ignores procedural justice and institutional safeguards in modern legal practice, thus its application in contemporary legal systems has limitations.

(b) *Legal system and right protection*

(i) *Neglect of the role of institutional safeguards*

Jhering's idea of the struggle for rights relies too much on individual initiative and struggle behaviour, and ignores the key role of the legal system in the guarantee of rights. In a modern society governed by the rule of law, the law is not only a tool for safeguarding individual rights, but also a core mechanism for maintaining social order and justice. The realization of rights should not depend only on individual struggles, but also on a sound legal system to ensure the acquisition and maintenance of rights.

In modern society, the improvement and self-adjustment capacity of the legal system has gradually become the main means of guaranteeing rights. The legislature provides members of society with a legal basis for the protection of rights through legislation, the judiciary ensures the realization of rights through fair judgments, and the law enforcement agencies guarantee the implementation of rights through effective enforcement. This institutionalized guarantee mechanism greatly reduces the need for individual rights to depend on personal struggle. Jhering neglected the role of this institutional guarantee, placing too much reliance on individual struggle for the realization of rights, and failing to fully recognize the capacity of the legal system to improve itself in modern society.

(ii) *Combination of legal feelings and institutional safeguards*

In modern society, it is difficult for legal feelings to exist independently of institutions. The legal system provides the framework and rules for the realization of rights, while legal feelings provide individuals with moral motivation and legitimacy. The two should be combined with each other, not opposed to each other. Legal feelings provide an ethical basis for the struggle for rights, enabling individuals to feel a sense of moral responsibility and justice in the face of rights violations, thus promoting the realization of rights. However, legal feelings alone are not enough to ensure the realization of rights; it needs the support of institutional guarantees. The legal system provides clear rules, procedures and protection mechanisms for the realization of rights, enabling individuals to rely on a stable institutional framework in their struggle.

Therefore, in modern society, the struggle for rights needs to rely not only on individual legal feelings but also on institutional guarantees. The combination of the two can more effectively promote the realization of rights and the maintenance of social justice. Through the continuous improvement of the legal system, the legal feelings can be better expressed and implemented, so that the struggle for rights is not only an individual action, but also become a social whole to promote the progress of the rule of law.

(c) *The realistic dilemma of right struggle*

(i) *The complexity of the struggle for rights in modern judicial practice*

Jhering's theory of the struggle for rights stresses the necessity for individuals to realize and defend their own rights through struggle, but in modern judicial practice, the struggle for rights is faced with a number of practical dilemmas. First of all, the modern society's legal relations and rights violations are increasingly complex, the object of the rights struggle is no longer a simple individual or group, but may involve multiple interests of the game. Individuals in the face of complex legal issues, it may be difficult to achieve their own rights through the simple act of struggle. Secondly, procedural justice and institutionalized rights protection are emphasized in modern legal systems, which means that the realization of rights must be accomplished through standardized legal procedures and institutional arrangements. In this context, the individual's struggle for rights often needs to rely on the help of legal procedures rather than on individual efforts alone. In modern judicial practice, the path for individuals to

realize their rights and interests through the struggle for rights is increasingly dependent on institutional support rather than on individual action in the struggle alone.

(ii) **Constraints of economic, social and cultural factors on rights struggle**

The struggle for rights in modern society also faces the constraints of economic, social and cultural factors. The success of the rights struggle often depends on a variety of factors such as an individual's social status, economic capacity, and knowledge of the law, rather than solely on an individual's sense of morality and justice. Disadvantaged groups are at a disadvantage in the struggle for rights and often find it difficult to realize their legal rights and interests through individual acts of struggle. This further reveals the limitations of Jhering's theory: his theory fails to fully take into account the complexity of rights struggle in modern society, especially the disadvantaged position of vulnerable groups in the legal system.

Jhering's theory of rights struggle provides a new perspective for jurisprudence, emphasizing the necessity for individuals to realize and defend their rights through struggle. However, in the modern rule of law society, Jhering's theory faces many challenges. Firstly, he relies too much on the individual's rights struggle behaviour and ignores the importance of the legal system in rights protection. Secondly, although legal feelings provide an ethical basis for rights struggle, their application in modern complex legal systems faces practical difficulties. Finally, the struggle for rights in modern judicial practice faces practical difficulties, especially in the protection of the rights of vulnerable groups, where it is difficult to realize their legitimate rights and interests through individual struggle alone. Therefore, Jhering's theory needs to be combined with the modern legal system in order to better adapt to the needs of contemporary rule of law society and promote the realization of social justice.

(d) ***Legal and moral obligation in the struggle for rights***

At the heart of Jhering's idea of the struggle for rights lies his dynamic understanding of the nature of rights. According to Jhering, the life of rights lies in the struggle, and the realization of rights depends not only on their conferral by law, but also on their active individual and collective striving and defence. He emphasized that all important social changes and legal progress were gained through the struggle for rights. This idea not only reveals the struggling nature of rights, but also delves into the ethical and legal value of rights struggles. On the ethical level, Jhering's idea of rights struggle highlights the sense of moral responsibility in the realization of rights. He believes that giving up rights is not only an abandonment of individual self-interest, but also a betrayal of social justice. Therefore, the struggle for rights is not only a legal act, but also a moral obligation. Individuals defend their rights through struggle and at the same time contribute to social justice and order. At the legal level, Jhering's thought emphasizes the importance of rights struggle for the construction of the rule of law. He points out that the perfection of the legal system and the realization of social justice depend on the active defence of individual rights. Through the struggle for rights, the law is able to continuously adjust and progress to better suit the changes and needs of society. This idea provides a theoretical basis for the construction of a modern society based on the rule of law, emphasizing the dynamic balance between individual rights and social justice. The duality of the struggle for rights is reflected in the harmonious development of individuals and society, rights and justice. While individuals realize their rights through struggle, they are also promoting the development of the legal system and social justice in the whole society. This duality makes the struggle for rights not only a result of individual behaviour, but also a driving force for social progress. Jhering's idea of the struggle for rights has important practical value in the construction of the modern rule of law, especially in enhancing the awareness of civil rights and promoting social justice, which plays a positive role.

Jhering's theory of legal feelings further deepens the ethical foundation of the idea of rights struggle. Legal emotion refers to the sense of justice and moral responsibility that individuals feel when facing rights violations, and it is an important intrinsic motivation that drives the rights struggle. According to Jhering, the rights struggle is not only a legal act, but also a moral obligation driven by emotion. Legal feelings provide ethical justification for individual rights struggle, so that individuals can feel the responsibility and obligation to defend their rights in the face of rights violations. In the modern rule of law society, the combination of legal feelings and the legal system is of great significance. Although legal feelings for individual rights struggle provides moral motivation, but its independent of the legal system limitations should not be ignored. Modern rule of law society depends on the soundness and perfection of the legal system, individual rights struggle must be carried out within the institutional framework. Therefore, legal feelings need to be combined with the legal system to ensure the legitimacy and effectiveness of the rights struggle. The prospects for the application of legal feelings in the construction of the modern rule of law are mainly reflected in two aspects. Firstly, legal feelings can enhance citizens' awareness of their rights and promote more active participation by members of society in rights struggles and social affairs. By cultivating citizens' legal feelings, modern society can further strengthen the realization of social justice and the construction of a culture of the rule of law on the basis of the legal system. Secondly, the combination of legal feelings and the legal system can prompt the legal system to be more humane and closer to the actual needs of the society, making the law not only a tool for regulation, but also a means to achieve social justice.

CONCLUSION

In modern society, how to balance the individual rights struggle and the protection of the legal system is an important issue facing the construction of the rule of law. Although Jhering's idea of the struggle for rights emphasizes the individual's initiative in the realization of rights, it also needs to be combined with the guarantee mechanism of the modern legal system in order to achieve social justice more effectively. Firstly, the legal system should continue to improve and develop to provide a stronger guarantee for the realization of individual rights. In this process, the legal system should not only regulate the process of realizing rights, but also provide institutionalized support for the struggle for rights, so that individuals can rely on the power of the legal system to fight in the face of rights violations. Through the combination of institutional guarantee and procedural justice, the individual rights struggle will be more powerful and effective; secondly, civic education should focus on cultivating the individual's legal feelings and rights consciousness, so that the rights struggle is not only a kind of legal behaviour, but also a moral responsibility and social obligation of the citizens. Through the cultivation of legal feelings, citizens can participate more actively in social affairs and contribute to social justice and legal progress. In this process, the legal system should play a guiding role to ensure the organic combination of legal feelings and legal practice, so that the struggle for rights has not only moral legitimacy, but also legal legitimacy. Finally, with the development of society and the continuous improvement of the legal system, the form and content of the struggle for rights will also change.

The future rule of law society should further promote the realization of social justice on the basis of guaranteeing individual rights. Jhering's idea of rights struggle provides us with valuable theoretical resources, on the basis of which we should explore more ways to realize individual rights and social justice in the future, so that the rights struggle will become a lasting impetus for the construction of a society based on the rule of law. Jhering's idea of rights struggle reveals the complex relationship between individual rights and social justice by emphasizing the dynamic nature of rights. His theory of legal feelings further deepens the ethical foundation of the rights struggle and provides rich ideological resources for the construction of a modern society based on the rule of law. Through the combination of

institutional safeguards and individual struggles, a modern society under the rule of law can more effectively achieve the harmonious development of social justice and individual rights. In the future construction of the rule of law, how to balance the struggle for individual rights and the protection of the legal system will continue to be an important topic of our attention. Jhering's ideas will continue to play an important role in this process, guiding us on the road to realizing social justice and individual rights.

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PRESERVATION AND RENEWAL OF ETHNIC ARCHITECTURAL CULTURE IN QIANDONGNAN PREFECTURE: CASE STUDY IN BASHA MIAO VILLAGE

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ABSTRACT

This scholarly endeavor explores the quintessential characteristics of ethnic architecture in Qiandongnan, with an in-depth focus on the Basha Miao Village. It commences by meticulously analyzing the historical evolution, stylistic diversity, and salient features of the region's ethnic architecture. Notable emphasis is placed on the Miao and Dong ethnic groups' influence, the strategic use of pine and cedar as the principal construction materials, the venerable craftsmanship of ancient concave and convex buttress structures eschewing iron nails, and the distinctively sloping roofs adorned with fired clay tiles. The paper then accentuates the architectural peculiarities of Basha Miao Village, underscoring its unique geographical adaptability and its innovative construction system, both of which are of paramount importance for academic inquiry. A meticulous delineation follows, portraying the current state of Basha Miao Village's architecture, with a spotlight on its traditional wooden structures, the ingenuity of low and multi-story stilt houses, and the meticulous spatial arrangement that encapsulates the architectural legacy of the traditional villages. In conclusion, the paper embarks on a thorough examination of the current land use for village construction, the state of residential construction, and a forward-looking development assessment. This research not only imparts profound insights and a nuanced understanding of the ethnic architectural heritage in Qiandongnan but also paves the way for future studies. It sets the stage for further exploration into sustainable development models, the integration of modern technologies with traditional practices, and the formulation of policies that will ensure the harmonious coexistence of cultural preservation with socio-economic progress, thereby honoring the rich tapestry of Qiandongnan's ethnic architectural legacy for generations to come.

Keywords:

Ethnic Architecture, Basha Miao Village, Traditional Construction Techniques, Sustainable Development, Cultural Heritage Preservation

INTRODUCTION

Qiandongnan Autonomous Prefecture is a region of China with a high concentration of ethnic minorities, including the Miao, Buyi, Dong, and 10 other ethnic minorities. The unique traditional ethnic architecture of Qiandongnan Prefecture integrates ethnic history, ecology, and architectural skills and has been called a "living fossil of anthropology" and "the world's largest ethnic museum. These traditional ethnic buildings have carried a rich human spirit, customs, and culture. Nowadays, under accelerated urbanization, the preservation and renewal of the ethnic architectural culture in Qiandongnan have become a matter of great concern for the local government.

According to research data from the China Village Culture Research Center (Hu & Binbin, 2012), as of 2004, there were 9,707 ethnic architectural traditional villages with distinctive features in China. By 2010, there were only 5,709 left, a decrease of 7.3% per year, or an average of 1.6 ethnic architecture ancestral villages per day. In the context of revitalizing ethnic architecture, this research proposal focuses on an in-depth study of ethnic architecture in Qiandongnan (taking BaSha Miao Village as an example), which helps to systematically analyze the different characteristics of the ethnic architecture in Qiandongnan and summarize the relationship between ethnic elements and architectural forms. Contemporary, combined with modern architectural design techniques, provide more help for preserving and renewing an ethnic architectural culture in Qiandongnan.

CHARACTERISTICS OF ETHNIC ARCHITECTURE IN QIANDONGNAN

The history, style, and main characteristics of the ethnic architecture of Qiandongnan, China: The ethnic architecture of Qiandongnan is represented by the Miao and Dong. Its most distinctive feature is the all-wooden architecture made of pine and cedar wood as building materials. It is assembled using ancient concave and convex buttresses and without any iron nail connections, with sloping roofs covered with clay-fired tile (Li & Zhenlai, 2005). The earliest surviving ethnic architecture is the wooden pagoda at Zengchong Dong Village, over 350 years old. The ethnic architecture of Qiandongnan has been passed down and continued to be used for thousands of years because the architecture has become a carrier of ethnic culture (Shi & Hefang, 2015). From the solemn ceremonies held during the construction of the houses to the totemic symbols carved on the buildings is strong evidence of the combination of ethnic elements with architectural design. The ethnic architecture of Qiandongnan plays a vital role in preserving ethnic culture. In addition, in a study of the characteristics of ethnic architecture in Qiandongnan, it was analyzed that the biggest reason for the formation of local ethnic architecture is the enclosed mountainous geographical factor. Although the mountains and forests provided a large amount of timber as a building material, the lack of flatland buildings was built by raising a wooden platform from the edge of the foundation with wood to merge with the original foundation. On the one hand, this saves land. On the other hand, it reduces deforestation, which shows that ethnic architecture also reflects the early awareness and behavior of the ancient people towards environmental protection.

CHARACTERISTICS OF BASHA MIAO VILLAGE ARCHITECTURE

Basha Miao Village in Qiandongnan, China, is a remarkable ethnic enclave with a storied past that spans millennia. Renowned as one of China's most enigmatic Miao settlements, it preserves a rich tapestry of traditional practices, including hunting and farming, which have been passed down through generations. This village stands out as one of the last in the country where the legacy of gun-toting tribes persists, symbolizing a warrior spirit that is deeply ingrained in its cultural identity. The Miao people here maintain a vibrant community life, characterized by strong familial and communal bonds, and are known for their exquisite silver craftsmanship and vibrant, hand-embroidered attire. Despite the challenges of modernization, the village continues to cherish and promote its cultural heritage, offering visitors an unparalleled glimpse into a way of life that is both ancient and enduring.

The Basha Miao settlement and village architecture are unique in their geographical adaptation. The construction system is mature, containing a wealth of geographical adaptation techniques and green experiences that are highly valuable for research (Huang & Dong, 2019). In the 20 years between 1996 and 2007, the Basha Miao Village has maintained its original way of life. Only a tiny part of the culture and building techniques of the ethnic group are now present in the modern culture and forms of the Miao village (Kuang & Huimin, 2010). In addition, the current promotion of green building, digital building and BIM technology also contributes to the preservation and improvement of national culture (Yusuf, Manteghi, & Roslan, 2021; Rashid & Husin, 2021; Anuar & Zainal Abidin, 2015).



Figure 1: 3D scanning model of Basha Miao Village in Basha Miao Village

Enveloped by the undulating contours of the surrounding topography, the village of Basha emerges as a distinctive settlement, richly endowed with the Chinese fir (*Cathaya argyrophylla*), a species esteemed for its remarkable resilience to warping, decay, and infestation by insects. The bark of this fir, recognized for its superior qualities, serves as an optimal roofing material, integral to the structural integrity of the village's traditional edifices, predominantly constructed from this robust and durable timber. Situated atop a landscape characterized by a significant elevation gradient of approximately 200 meters, the traditional wooden architecture of Basha Village is underpinned by robust stone foundations. This harmonious fusion of construction and environment culminates in a striking visual tableau of timber-framed dwellings, seamlessly integrated within an emerald tapestry of venerable arboreal canopies and bamboo thickets. The village exudes an ambiance of serenity and rustic refinement, a rare and alluring quality that is both captivating and of significant scholarly interest.

The traditional dwellings in Bashavillage are characterized by modest proportions, mainly comprising two types: low stilts houses and multi-story stilt houses. Perched on the ridges, the low stilt houses are primarily built to withstand strong winds and prevent structural distortion or collapse. These structures lack ground-level floors, with floorboards placed about 1.5 feet above the ground to prevent moisture seepage. The interior layout and features are akin to those of multi-story stilt houses. Multi-story houses typically consist of three levels: the ground floor, used for livestock husbandry, poultry rearing, firewood storage, and milling; the second floor, featuring a hearth, long corridors, and bedrooms; and the third floor, utilized for storing miscellaneous items, with water buffalo horns hung on the floor beams and crops tied to the central pillars. Livestock in low stilts houses are mainly kept in adjacent sheds. Most residences comprise two or three rows of rooms and sheds, constructed from Chinese fir and topped with a gable roof, covered with either Chinese fir bark or small blue tiles. Each household is equipped with a hearth, serving as a space for cooking, hospitality, and heating. Festive rituals are also conducted around the hearth, which serves as a focal point for ceremonies. A square k'ang rack, over a meter in size, is often installed above the hearth for drying grains. Due to fire safety and hygiene concerns, hearths have been relocated to the ground floor, with many k'ang racks removed, and livestock, poultry, and fertilizers gradually relocated outside the living quarters. The second floors of multi-story stilt houses typically feature long corridors, approximately 1.5 meters wide, providing a space for cooling off, resting, dining, women's needlework, and weaving. The residences feature small sliding windows, seldom opened, with some even remaining permanently closed.

Built along the contours of the mountains, Bashavillage exhibits a tiered layout typical of Miao ethnic villages, showcasing a harmonious and well-ordered arrangement that reflects the distinctive character of the culture. As one of the representative Miao cultural villages in southeastern Guizhou Province, it preserves relatively intact historical relics and cultural heritage, accompanied by a wealth of historical and cultural information, demonstrating a high cultural standard. It serves as a testament to the lifestyle and cultural characteristics of the region during the Ming and Qing dynasties, possessing significant historical, artistic, and scientific value.

CURRENT STATUS OF CULTURAL PROTECTION IN BASHAVILLAGE

Preservation of the Overall Spatial Layout of Traditional Villages

Within the region, there exist three core traditional villages: Liangjiao, Dazhai, and Zaige Xinzhai. Overall, these traditional villages have largely maintained the traditional landscape and layout of mountainous regions, along with the functional arrangement of raised granaries. The spatial organization seamlessly conforms to the terrain, extending from the foot of the mountain to its summit, harmonizing with the natural environment while maintaining an organic integration of architecture with the landscape, mirroring the natural slope of the terrain.

The main streets and branching road networks of traditional villages sprawl outward from the inside, with internal pathways following the irregularities of the terrain, stretching freely. Each village has a main footpath, winding up the mountain contours, extending along contour lines, with secondary paths branching off, often featuring stepped pathways, providing access to every household.

Current State of Traditional Miao Ethnic Architecture in Bashavillage

Traditional Architectural Style

Bashavillage's traditional dwellings are relatively small in scale and can generally be classified into two types: low stilts houses and multi-story stilt houses. Residents situated on the ridges predominantly inhabit low stilts houses, primarily for protection against strong winds. These structures lack ground-level floors, with floorboards placed approximately 1.5 feet above the ground to prevent moisture seepage. The interior structure and layout are similar to those of multi-story houses. Multi-story houses typically consist of three levels: the ground floor, used for livestock husbandry, poultry rearing, firewood storage, and milling; the second floor, featuring a hearth, long corridors, and bedrooms; and the third floor, used for storing miscellaneous items, with water buffalo horns hung on the floor beams and crops tied to central pillars. Livestock in low stilts houses are mainly kept in adjacent sheds. Most residences consist of two or three rows of rooms and sheds, constructed from Chinese fir, with gable roofs covered in Chinese fir bark or small blue tiles. Each household is equipped with a hearth, serving as a space for cooking, hospitality, and heating. Festive rituals are also conducted around the hearth, serving as a ceremonial space. A square k'ang rack, often over a meter in size, is installed above the hearth for drying grains. Currently, due to fire safety and hygiene considerations, hearths have been relocated to the ground floor, with many k'ang racks removed, and livestock, poultry, and fertilizers gradually relocated outside the living quarters. The second floors of multi-story stilt houses typically feature long corridors, approximately 1.5 meters wide, providing a space for cooling off, resting, dining, women's needlework, and weaving. Residences feature small sliding windows, seldom opened, with some remaining permanently closed.

Built along the contours of the mountains, the well-ordered overall layout of each village reflects the typical character of the Miao ethnic village, providing a solid basis for the study of the living space and ecological environment of Miao ethnic villages. As one of the representative Miao cultural villages in southeastern Guizhou Province, it preserves relatively intact historical relics and cultural heritage, accompanied by a wealth of historical and cultural information, demonstrating a high cultural standard. It serves as a testament to the lifestyle and cultural characteristics of the region during the Ming and Qing dynasties, possessing significant historical, artistic, and scientific value.

Currently, Bashavillage's tourism development is rapidly expanding, leading to significant demands for the renovation, expansion, and construction of traditional village buildings within the region. The contradiction between protection and development is becoming more prominent, with inadequate guidance and control over architectural style, resulting in a certain degree of damage to the traditional architectural landscape due to the construction of numerous new reinforced concrete structures.



Figure 2: Basha Miao Village Architectural Style

Preservation of Granaries and Drying Racks

Granaries and drying racks remain well-preserved and functional to this day, with almost every household having them. To prevent fires, granaries and drying racks are generally built around the periphery of the village, hence their age tends to be quite old. Granaries typically feature suspended gable roofs, covered with Chinese fir bark or small blue tiles, supported by four pillars, often square or rectangular in shape. Some granaries are accompanied by annexes, providing space for people to enter and exit the granary doors and to place ladders. Drying racks are wooden structures used for air-drying glutinous rice. During the golden autumn season, drying racks adorned with hanging grains stand like golden walls along the edges of the village, forming a beautiful landscape.



Figure 3: Preservation of Granaries Drying Racks



Figure 4: Drying Racks 3.2.3 Village Gates

Each natural village in Bashavillage has its own village gate, constructed from Chinese fir wood, most of which appear rather worn and aged. The village gates of Dazhai, Wangjiazhai, and Zaizhuangzhai are the largest, featuring a "信鼓" (xin gu), a traditional drum, although in modern times, they have lost their function of deterring thieves and are only effective during ritualistic activities. Village gates serve as the iconic entrance to the village, historically functioning as a defense mechanism. While this function has dissipated over time, they remain the passage into the village, symbolizing the territorial and cohesive essence of the village community. Village gates represent typical ethnic architecture, often adorned with thorny plants, creating an ecological gate that harmonizes with nature, showcasing the ecological environment where humans coexist harmoniously with nature.



Figure 5: Village Gates

CURRENT STATUS OF VILLAGE CONSTRUCTION LAND USE

Within the planned area, the current area of construction land for rural residential areas is 21.12 hectares, with a registered population of 2801 people, resulting in an average construction land area of 75.54 square meters per person.

CURRENT STATUS OF RESIDENTIAL CONSTRUCTION

Layout Characteristics

Residential areas within the planned area are situated along the mountains and rivers, neatly arranged and stacked atop one another. The residents' settlements extend from the foot of the mountain to the ridge, following the flow of the water, presenting a gentle and expansive layout. The buildings are relatively low in height, harmonizing with the mountain terrain, and striving to preserve the integrity of the mountain's ecosystem, achieving an organic integration of architecture with the natural landscape.

Village Landscape Pattern

Village sites are selected to accommodate natural constraints and early ethnic defense needs, resulting in a terraced layout of "mountains—farmland—village—valley—water body" under the spatial characteristics of the mountains. Given the mountainous terrain of Guizhou, Miao villages are constructed along the mountains and rivers, utilizing slopes to create more usable space. The architectural groups are staggered in height, compact and exquisite, coexisting harmoniously with the natural environment, creating a unique landscape pattern. Within the planned area, residential areas naturally form a unified

architectural style, primarily using abundant wood and stone resources, complemented by brick, tile, and earth materials for stilted houses, resulting in a unified overall style and a distinctive landscape.

Village Appearance

Overall, the current buildings within the planned area are traditional wooden stilted structures, mostly with sloping roofs, with relatively good building quality. In the protected areas of traditional villages, the architectural style is relatively consistent, although there are very few structures that do not conform to the overall architectural pattern. In areas outside the protected traditional villages and non-traditional village areas, some new buildings adopt modern European-style architectural styles, which are highly discordant with the overall architectural pattern.

DEVELOPMENT ASSESSMENT

Overall Trends and Opportunities

1. Implementation of Rural Revitalization Strategy

Since the 19th National Congress of the Communist Party of China, the rural revitalization strategy has become a crucial measure to build a beautiful China and achieve common prosperity among the people. Guizhou Province has successively introduced strategic plans for rural revitalization, as well as six actions for the construction of "Four in Rural Homes ▪ Beautiful Villages" and its infrastructure, emphasizing the direction of "creating characteristics," "highlighting pastoral scenery," and "enhancing rural areas."

In 2021, the provincial government formulated and issued the "Five-Year Action Plan for the High-Quality Development of Traditional Villages in Guizhou Province (2021-2025)," highlighting the importance of high-quality development of traditional villages as a new initiative in rural revitalization, aiming to cultivate traditional villages into "beautiful homes with visible mountains, visible waters, and memorable hometown feelings."

2. Prospects for Cultural Experience-based Rural Tourism Market

Currently, with the improvement of people's living standards, there has been a qualitative shift in consumption concepts. Short-distance holiday trips and weekend leisure travel are gradually becoming popular, with ecological leisure vacation tourism, health and wellness tourism, and folk cultural experience tourism increasingly becoming mainstream in the tourism market. Traditional villages, as important carriers of rural tourism, will play a significant role in future rural revitalization.

3. High-Level Attention from County and Township Governments

This planning project, as a pilot project for village planning in the Bmei Township, has received attention from both county and township governments. In the context of rural revitalization, how to vigorously develop rural tourism, promote high-quality development of traditional villages, and carry out rural planning and construction work has become a key focus of this planning project.

4. High Enthusiasm of Villagers for Tourism Development and Strong Desire to Improve Living Standards

Through current status discussions and questionnaire surveys, villagers have shown high approval for this village planning project and have raised many genuine demands. There is high enthusiasm for village development, and villagers hope to improve their living standards through infrastructure improvement and tourism development.

Advantages and Endowments

1. Good Ecological Landscape and Natural Environment

The planned area boasts lush forest vegetation and excellent ecological environment, with a forest coverage rate of 80% and stunning natural scenery. Ancient trees are abundant throughout the planned area, distributed in various natural villages. Additionally, due to topographical reasons, the planned area features unique terraced landscapes.

2. Deep Ethnic Culture with Preserved Traditional Lifestyles and Folk Customs

The planned area comprises five natural villages, with three core traditional villages, where some residential buildings are historical traditional structures that are well-preserved, representing typical Miao ethnic villages. The intangible cultural heritage of the Miao ethnic group, such as Miao embroidery, lusheng dance, and Miao New Year, is well inherited and celebrated in the planned area. All Miao customs and festivals can be experienced in the planned area, including the Spring Festival, the Third Month Third (Yingshan Red Festival), Qingming Festival, Dragon Boat Festival, Zhehe Festival, Swing Festival, Double Ninth Festival, Lusheng Festival, and Miao New Year.

CONSTRAINTS AND RESTRICTIONS

Lack of Industrial Support

The planned area relies mainly on agriculture and income from migrant work. Agricultural income is primarily derived from planting and breeding, while the secondary industry in the village is in its early stages, and the development of the tertiary industry is relatively low. The current industrial development is relatively single, unable to provide more support for village development. The single industry has also led to an increase in the number of villagers working outside the village, limiting the vitality of village development.

Failure to Form a Cultural Brand for Miao Embroidery Inheritance, Failing to Drive the Development of Other Industries

The planned area lacks tourism supporting facilities. Although Miao embroidery and silverware making techniques are exquisite, they are still carried out on a household or individual basis, failing to form a unified cultural brand and unable to drive the development of other industries.

Single Regional Tourism Nodes with Short Routes and Visiting Time

The tourist nodes and activities within the planned area are single, with short tourist routes and limited visiting time, failing to establish temporal and spatial continuity.

Lack of Prominent Village Construction Features, Urgent Need for Improvement in Living Environment

The overall architectural style within the core protected areas of traditional villages is relatively consistent, but there are some structures that disrupt the overall landscape and require rectification. Outside the core protected areas of traditional villages, the incongruity between new European-style buildings and traditional Miao stilted houses affects the tourist experience, necessitating urgent improvement in the living environment.

RISKS AND CHALLENGES

Identifying Development Characteristics and Building Core Tourism Attractions

Identifying the most attractive tourism selling points based on the characteristics of tourism resources in the planned area, planning tourism products reasonably, and forming an integrated tourism area covering "food, accommodation, transportation, shopping, and entertainment" is the biggest challenge for the planned area. The goal is to attract and retain visitors effectively.

Balancing Tourism Development with Traditional Village Protection

While developing tourism, it is crucial to fully respect the living habits and production methods of traditional village residents, improve the production and living conditions of traditional villages, and prevent hollowing out and excessive commercialization of traditional villages.

Transforming Traditional Crafts like "Miao Embroidery" into Industries

Miao embroidery, as a unique traditional craft of the Miao ethnic group, is mainly used by villagers for personal use at present. The plan relies on the development of tourism to scale up the display, production, inheritance, and sales of Miao embroidery into a standardized industrial chain.

Strengthening Integration and Linkage among Industries to Promote the Development of Comprehensive Tourism

Utilizing the driving force of the tourism industry, it's essential to properly develop the planting, breeding, traditional handicrafts, and other industries in the planned area, construct a new industrial system, and promote the comprehensive development of tourism in Bmei Township.

Uncertainty in Selecting Specialized Agriculture and Animal Husbandry Industries and Market

The current featured industries in the planned area mainly include rice field fish farming, chili and passion fruit cultivation, beekeeping, and a small amount of poultry and livestock breeding. Due to the significant market uncertainty, the economic resilience of the industries is relatively weak.

CONCLUSION

The BaSha Miao Village has been in existence for more than a thousand years. It has become a representative of ethnic architecture and culture with high cultural, historical, economic, and environmental value in the Qiandongnan region. In China's rapid urbanization, the destruction of ethnic architecture is a common problem. Some ethnic buildings of cultural and historical value have been in disrepair for many years. Many of the local traditional buildings have become dangerous. Moreover, the old conventional buildings can no longer meet the villagers' modern needs. They are even less capable of receiving tourists, and their tourist and economic value are not reasonably exploited. The preservation and renewal of the ethnic architectural culture of Qiandongnan is now a long-term goal to which the local government attaches the most significant importance. The design of a more modern landmark building with traditional ethnic elements will enable the local ethnic architecture to be better preserved and developed. At the same time, it will allow the tourism and economic value of the BaSha Miao Village to be exploited in a way that will increase the villagers' income and the government's tax revenue. Finally, the sustainable development of the BaSha Miao Village will become a model for the conservation and renewal of the ethnic architecture of Qiandongnan.

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THE IMPACT OF EDUCATION ON THE ELDERLY WELL-BEING: A META-STUDY

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ABSTRACT

In light of the global demographic shift towards an aging population, ensuring the well-being of the elderly has emerged as a pressing concern. Consequently, a multitude of researchers have offered valuable perspectives on this critical issue. Seeking to contribute to this discourse, this study conducted meta-research on a related research objective to explore the impact of education on the well-being of the elderly. Elderly education is a part of a lifelong education, which gives effects positively on the well-being of the elderly. This study used data screening, assessing education and the well-being of the elderly based on the article published from 2019 to 2023. The findings of this study suggested that education can be effective in improving the elderly well-being, mainly reflected in the positive effects of elderly education on their emotional regulation, social integration, cognitive ability, and quality of life. The findings also shed light on issues of self-actualization and positive emotions in elderly well-being. The findings of this comprehensive study highlight the impact of education on the elderly well-being, while emphasizing the need for the improvement. These insights have important implications for education practitioners and call for attention to the effectiveness of elderly education in terms of elderly well-being.

Keywords:

Education, Well-being, Elderly, Influencing Factors, Meta-research.

INTRODUCTION

The global population is experiencing rapid aging, a phenomenon that stems from the inevitable transformation of population structure. It stands as a significant challenge confronting human society in the 21st century. (Liu, 2021; Nagarajan et al., 2023). According to Dsouza, Chakraborty and Kamath (2023), the world is facing a demographic revolution, with rapidly increasing numbers of people over 60 in almost every country. It is an indisputable fact that population aging is becoming increasingly serious, and population aging has become a global phenomenon (Sarkar et al., 2023). The trend of population aging is obvious, mainly due to the increase in life expectancy, decline in fertility rate and improvement in health status (Dsouza et al., 2023). According to the data from "World Population Prospects: The 2019 Revision", the age group proportion of the global population, after 2020, the world's elderly population will increase sharply. By 2050, the proportion of the global population aged 65 and over is expected to increase from about 703 million in 2020 to about 2.13 billion, accounting for 9% of the total population age group to 16%. (See the 2019 Revised World Population Prospects for more details), as shown in Figure 1. Therefore, how to improve the well-being of the elderly has not only become a topic of medicine, gerontology and psychology (Olatunji et al., 2023), but also the focus of education.

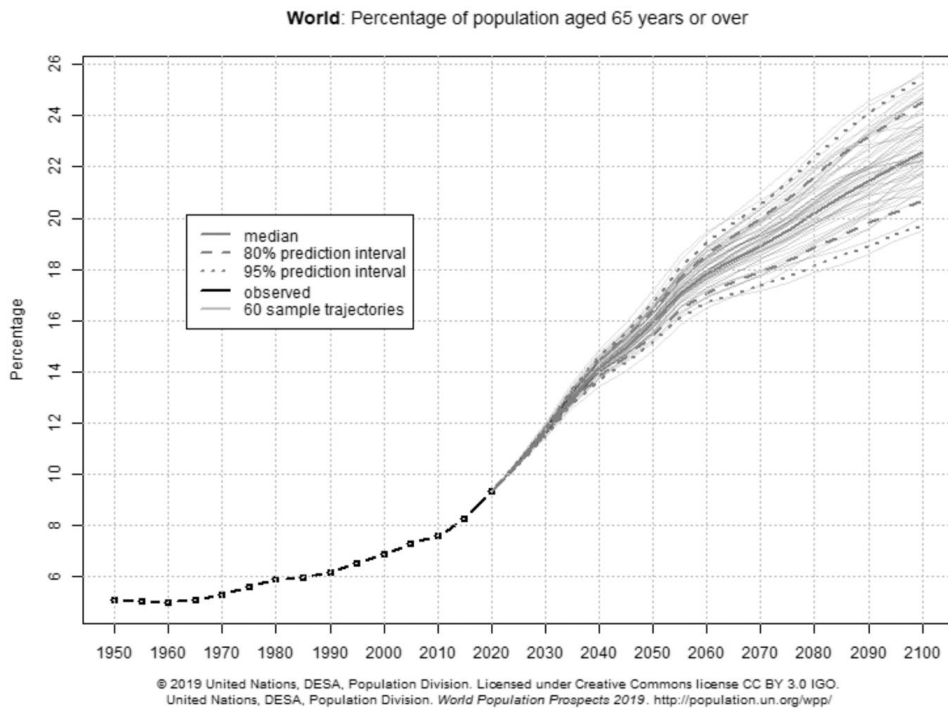


Figure 1: Estimated percentage of world population aged 65 or over (United Nations Secretariat, 2019)

Educating the elderly is a component of adult education and represents the culmination of lifelong learning (Zheng, 2020). It serves as a critical embodiment of the principle of lifelong learning, safeguarding the educational rights of older individuals and ensuring their access to rational education, thereby upholding their human rights (Xia & Yu, 2020). According to Fan (2020) and Hong et al. (2023) that advancement of elderly education contributes significantly to the holistic progression of society. Fan (2020) has emphasized that the well-being of the elderly holds the key to achieving societal harmony, asserting that education for this demographic fosters societal cohesion. Correspondingly, Hong et al. (2023) emphasized that education for the elderly is an effective measure to promote healthy aging and establish age-friendly communities. Adriani and Elmaghfuroh (2023) have underscored the efficacy of tele-nursing-based health education in enhancing the awareness of COVID-19 prevention strategies among older individuals with diabetes. Evidently, education yields a significant affirmative impact on the elderly. Therefore, understanding the impact of education on the well-being of the elderly and focusing on which factors affect education, and developing methods to improve their well-being through education, remains a top priority.

LITERATURE REVIEW

Well-being is not an academic term and there is no uniform definition, for the most part, well-being research is based on researchers' measurements. In different research articles, well-being has been described as various expressions, such as “subjective well-being” (Wang, 2022), “life satisfaction” (Colucci et al., 2022), “psychological well-being” (Galiana et al., 2020), “positive emotions” (Won et al., 2020), “social well-being” (Banerjee et al., 2020), etc. Debates about the connotation of well-being are most commonly divided into two categories: subjective well-being (SWB) and psychological well-being

(PWB) (Anglim et al., 2020). Bianchi (2021) pointed out that well-being is usually considered as subjective well-being (SWB), including three aspects of life satisfaction, positive affect and low negative affect. On the contrary, many philosophers have criticized the excessive focus on emotion in subjective well-being research, arguing that the evaluation of emotion cannot provide a clear answer to the meaning of well-being. Galiana et al. (2020) believe that the concept of well-being is the realization of one's individual potential. In addition, many scholars support that happiness encompasses both subjective well-being and psychological well-being, suggesting a potential relationship between these two concepts (Joshnloo, 2019; Moreta-Herrera, 2023).

The well-being of the elderly has always been one of the important focuses of scholars in the study of well-being. Many factors influenced changes in elderly well-being. First, Zhao and Tan (2022) and Peng (2021) all believed that there was no statistically significant difference in the well-being level of the elderly between genders. However, other scholars held the opposite view (Zheng, 2020; Wang, 2022; Deng et al., 2024). Deng et al. (2024) pointed out that the well-being level of women was higher than that of men. Zheng (2020) share the researchers conducted a questionnaire survey on elderly college students, and the results showed that women had higher well-being scores than men, and the gap between well-being scores was 1.718. On the contrary, Wang (2022) believed that the well-being level of male elderly people was higher than that of women. Second, Zhu et al. (2020) compared the economic status of the elderly and the family economic status of the elderly and local families and pointed out that the elderly with relatively high income had higher levels of well-being. Wang (2022) agreed with Zhu et al. (2020) and added that there were spatial and regional disparities in well-being levels, that is, older people living in wealthier areas were generally happier than those living in relatively less affluent areas. Won et al. (2020) and VanTienwoven et al. (2020) held the same ideas that identified social participation as one of the important factors affecting elderly well-being. VanTienoven et al. (2020) investigated the relationship between active participation time and life satisfaction among older adults in Belgium and the United States, using a general measure of life satisfaction as an indicator of well-being. The analysis of the study showed a correlation between active participation and life satisfaction. Similarly, Won et al. (2020) conducted a study on active physical activity and subjective well-being among Korean older adults. Findings suggested that physical activity could promote social engagement and enhance elderly well-being.

Zhu and Li (2021), Fan (2020), and Liu (2021) shared the same idea, all believing that education for the elderly could promote the social integration of the elderly. Zhu and Li (2021) reported an interview study with a group of elderly urbanized community residents. The results showed that geriatric education could accelerate the transformation of older people's identity, improve individual self-satisfaction and social integration, and promote urbanization, advocacy, and community building for social harmony. Fan (2020) stated that geriatric education could improve the quality of life of older adults, help them maintain physical function and productivity for a longer period, increase social participation, make new friends, and reduce alienation by analyzing the benefits of geriatric education in the context of active aging. Similarly, Liu (2021) demonstrated through a study of geriatric education activities in American museums that geriatric education could eliminate the negative impact of age discrimination on older people, build a friendly community for older people, enable older people to participate in meaningful educational activities, relieve loneliness, and provide a sense of purpose and opportunities to build good relationships with others. Likewise, Eufemia et al. (2023) demonstrated that there was a significant correlation between education for the elderly and happiness of the elderly, and cultural participation played a partial mediating role in the relationship between high-quality home care and happiness of the elderly. In addition, Elzohairy et al. (2024) pointed out that psychological education programs are an effective way for older people to cope with climate change and promote successful aging.

Dong et al. (2022) agree with Zheng (2020) that older people with higher education have higher levels of well-being. Zheng (2020) conducted a review of the well-being of students in geriatric education in senior colleges. The findings suggest that the education level of older adults has a significant impact on students' well-being scores. Later well-being levels increased with higher levels of education.

Similarly, Dong (2022) pointed out that the number of adult higher education schools is the main factor affecting the differences in well-being levels in different provinces. In addition, Wang et al. (2023), Rena et al. (2023), and Noguchi and Shang (2023) shared the same ideas that elderly education has a positive impact on the well-being of the elderly, especially in the field of art. Wang et al. (2023) pointed out that art is a way of expressing feelings and emotions, and art education activities have a positive impact on a person's psychological state and physiological parameters. Rena et al. (2023) proved that art is related to healthy aging, and they found that receptive or participatory participation in art activities lasting for more than four years is associated with good physical function, indicating that it may have some benefits for healthy aging. Similarly, Noguchi and Shang (2023) investigated the relationship between art participation and mental health among elderly people in Japan. They pointed out that active art participation frequency has a positive impact on the mental health of elderly people, and high art participation frequency is significantly correlated with higher levels of positive emotional scores.

Analyzing the factors influencing elderly well-being through education, as well as the aspects that these factors concentrate on, is a prerequisite for implementing elderly education and improving the well-being of the elderly.

METHODOLOGY

Meta-synthesis is an aspiring and popular method of synthesizing qualitative research results with the aim of obtaining opinions that are broader, more general, and more conceptually developed than any individual insight study. Sim and Mengshoel (2023) pointed that meta-synthesis includes the stages of formulating research questions, identifying relevant studies, extracting data, synthesizing findings, and interpreting results to generate new opinions or theoretical frameworks. In the context of meta-studies, the results of other studies were qualitatively analyzed. According to Hass and Springer (2014), meta-studies have the potential to allow for increased research productivity by providing an in-depth narrative description and allow for broad exploration. meta-research has emerged as a promising approach in organizational and management research (Habersang & Reihlen,2023). This investigation employed Google Scholar as the search engine for data collection, filtering the retrieved data using key terms such as "elderly education" and "well-being". The results were sorted based on relevance, with priority given to articles listed in SSCI, SCI, and Scopus databases. Additional selection criteria included publication dates between 2019 and 2023, and reports of evaluations conducted within educational institutions.

Based on article search and screening, this meta-analysis selected 10 articles for analysis, as shown in Table 1. Among them, one article was published in 2019, two articles were published in 2020 and 2021 respectively, one article was published in 2022, and four articles were published in 2023. According to Table 1, 10 articles were coded separately for easier analysis and discussion. Among them, A represents the article, and the numbers 1-10 refer to 10 articles respectively. For example, A1 refers to the first article in the list, A2 refers to the article 2, A3 refers to the article 3 and so on.

Table 1: Meta-Analysis Findings

| | Title | Author/s | Year | Journal |
|----|---|---|------|-------------------------------------|
| A1 | Towards Sustainability: The Involvement of the Elderly in the Educational Activities of NGOs in Lithuania | Edita Štuopytė | 2022 | Sustainability |
| A2 | Comparing the Effects of Group and Family-Centered Education in the Elderly Lifestyle | Shaafi M.S, Hosseini N, Akbartabar Toori M, Moqimi M. | 2020 | Journal of Clinical Care and Skills |

| | | | | |
|-----|---|--|------|---|
| A3 | The Integration and Development of Piano Art and Media Education and Its Influence on the Long-Term Care and Happiness of the Elderly People | Xuan Chen ^{1,2} , Fangwei Huang ³ and Yingfeng Wang ⁴ | 2021 | Frontiers in Psychology |
| A4 | Protective effects of education on the cognitive decline in a mental rotation task using real models: a pilot study with middle and older aged adults | Rahe, M., & Quaiser-Pohl, C. | 2023 | Psychological Research |
| A5 | The Role of Continuing Education on Elderly Memory: Islamic Perspective | Basuki, R., Latief, H., Bashori, K., & Suud, F. M. | 2023 | Islamic Perspective. In 1st Lawang Sewu International Symposium 2022 on Health Sciences (LSISHS 2022) |
| A6 | A Social Resource of Education for the Elderly in a Digital Society | Bolshunova, T., Grigorieva, N., & Maslova, O | 2023 | In 2023 3rd International Conference on Technology Enhanced Learning in Higher Education (TELE) IEEE. |
| A7 | The impact of art education and training on the well-being of the elderly | Xu Yanjun, Yu Qiong | 2023 | Adult and Higher Education Clausius Scientific Press, Canada |
| A8 | The Impact of the Educational Intervention on Sleep Quality and Psychological Well-being Among the Elderly People | Kaveh, M. H., Behmanesh, V., & Karimi, M. | 2021 | Malaysian Journal of Medicine & Health Sciences |
| A9 | Relationship between mental health and the education level in elderly people: mediation of leisure attitude | Belo, P., Navarro-Pardo, E., Pocinho, R., Carrana, P., & Margarido, C. | 2020 | Frontiers in Psychology |
| A10 | The Effect of the elderly's motivation to participate in lifelong education on their life satisfaction | Cho, K. W., & Choe, C. S. | 2019 | Asia-pacific Journal of Convergent Research Interchange |

Note: A: Articles, numbers 1-10 refer to 10 articles respectively. For example, A1 refers to the first article in the list, A2 refers to the article 2, A3 refers to the article 3 and so on.

RESULTS AND DISCUSSION

Štuopytė (2022) conducted a qualitative study focusing on group discussions, and stated the analysis of the educational activities of non-governmental organizations for the elderly in a region of Lithuania. Eight individuals participating in educational activities participated, with an average age of 67.5 years old. The research results indicate that educational activities have improved the social activities of the elderly, promoted social integration, increased communication and self-esteem, improved social skills, and expanded their social networks. Bolshunova et al. (2023) and Štuopytė (2022) have the same ideas that education is beneficial for the social integration of the elderly. Bolshunova et al. (2023) analyzed the national policies of the Russian Federation regarding elderly people, such as basic documents “the Action Strategy for the Interests of the Elderly by 2025”. They pointed out that education is one of the conditions for realizing the life potential of the elderly. On the one hand, education affects the reemployment of the elderly, and on the other hand, it can help them participate in social connections, overcome social distancing, and improve their adaptability. Actively participating in society is an important way for the elderly to improve their quality of life, and education can help them achieve this goal.

Belo et al. (2020), Kaveh et al. (2021), and Chen et al. (2021) hold the same ideas that education affects the emotions of the elderly, and education can effectively enhance their positive emotions. Belo et al. (2020) conducted a convenience sampling questionnaire survey on retirees residing in institutions in northern and central Portugal, aiming to explore the impact of education on the mental health of retirees. The research results indicate that older adults with higher levels of education exhibit better mental health and more positive leisure attitudes. Older people with lower levels of education experience higher levels of pain. Similarly, Kaveh et al. (2021) used a random sampling method to select samples from clients at the Borazjan Comprehensive Health Center in Iran and conducted a randomized education field-controlled trial on 90 elderly individuals with sleep disorders. Intended to conduct a 5-week activity and virtual learning educational intervention through lectures, group discussions, and other means. The research results show that behavioral intervention education is beneficial for alleviating psychological anxiety and improving mental health in the elderly, thereby improving their sleep quality. In addition, Chen et al. (2021) conducted a questionnaire survey on elderly people living in Guangzhou, Beijing, and Tianjin, China who participated in piano education and those who did not, with the aim of examining the changes in their mental health after participating in piano education compared to before. The research results indicate that after elderly people participate in piano education, with the increase of learning time, positive emotions and positive emotional experiences are improved, while negative emotions and negative emotional experiences decrease with the increase of piano learning time.

Rahe & Quaiser-Pohl (2023) and Basuki et al. (2023) maintaining a consistent view, they believe that education can improve the cognitive abilities of the elderly. Rahe & Quaiser-Pohl (2023) discussed the protective effect of education on cognitive decline in psychological rotation performance. They believe that cognitive decline caused by aging does not occur in the same way for everyone, and that education has a moderating effect on the impact of aging. Education for the elderly is not only a tool for acquiring new knowledge or verifying old knowledge, but also an important way to prevent cognitive impairment. Similarly, Basuki et al. (2023) pointed out that education will have a significant impact on the quality of life of the elderly. They used library research methods to explain the effect of continuing education on the memory of the elderly from an Islamic perspective. The research results indicate that continuing education can delay the decline of memory function in elderly people by increasing brain neural plasticity, which is very beneficial for protecting the neurological disorders that occur in the form of neurodegeneration in the elderly and affecting the decline of memory and cognitive function. And they particularly emphasize that the function of education is to transform natural development into directed development.

Shaafi et al. (2020), Xu and Yu (2023), Cho and Choe (2019) have the same ideas that elderly education improved the quality of life for the elderly. Shaafi et al. (2020) used purposive sampling to conduct three parallel randomized controlled field trials on 150 elderly people aged 60 to 74 in Yasuji,

Iran, including a group education group, a family centered education group, and a control group. The research results indicate that there is a statistically significant difference in quality of life between the family centered education group and group education and the control group. Both families centered education and group education effectively improve the quality of life of the elderly. And considering that the two types of educational interventions have similar effects, and the cost of home visits is relatively high, and more personnel are needed, it is recommended that group education be a suitable method to improve the lifestyle of the elderly. Xu and Yu (2023) pointed out that elderly education is a part of lifelong education, and elderly art education has a positive effect on improving the quality of life of the elderly. However, currently, there are still many problems in elderly art education, such as insufficient educational resources, overly simple educational content, and lack of enthusiasm among the elderly. Further optimization of elderly art education is needed. In addition, Cho and Choe (2019) conducted a quantitative study on 250 elderly people in K city, China. The results showed that elderly education provides an opportunity to improve quality of life by overcoming social alienation and promoting interpersonal relationships, effectively improving the life satisfaction of the elderly. Ma (2024) believes that participating in learning has a significant positive effect on the physical and mental health of the elderly. Liu (2023) has the idea that art education can help the elderly maintain a healthy mental and physiological state, enhance emotional communication, enhance aesthetic awareness, and promote the construction of social civilization.

Education, as a lifelong developmental process, continues to have active effects in old age. As shown in the results, findings from meta-studies suggest that continuing to learn and participate in educational activities can promote cognitive maintenance, emotional adjustment, social interaction, improve quality of life, and thus enhance their overall sense of well-being. Figure 1 shows the positive impact of education on the well-being of the elderly.

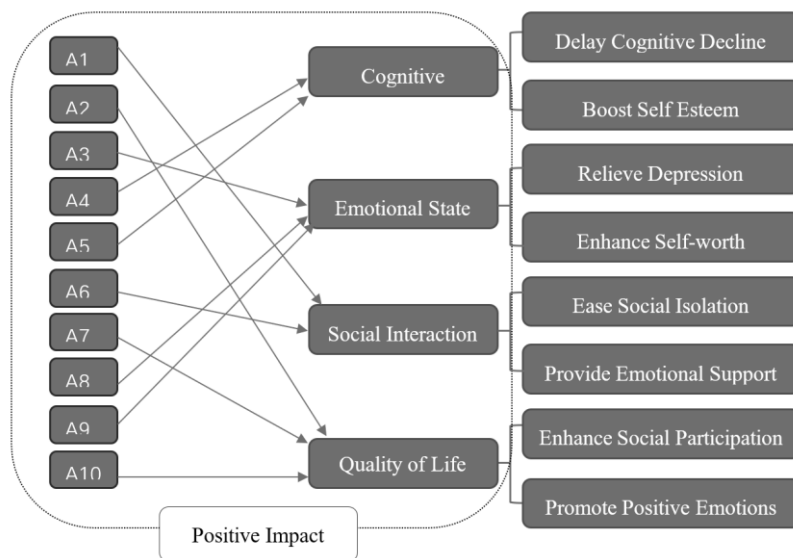


Figure 2: Positive impact of education on elderly well-being

SUMMARY OF RESULTS

According to the results of meta comprehensive research, elderly education is considered an important influencing factor for the well-being of the elderly and has a beneficial impact on their well-being. In 1989, Ryff proposed six dimensions that make up mental health include autonomy, control of the environment, positive relationships with others, self-acceptance, life goals, and personal growth. Although this study reveals some problems with elderly education, overall, elderly education can still produce various beneficial effects. Education, particularly in the context of elderly education, emerges as a powerful tool to enhance the quality of life, cognitive well-being, and social engagement among older individuals. The positive impact of education on the happiness of elderly people can be attributed to several factors. Firstly, A4 and A5 show that continuous learning and cognitive engagement through education can help maintain or even enhance cognitive function. This is consistent with the results proposed by Zheng (2020) and Wang et al. (2023) that education supports cognitive well-being, including memory, problem-solving ability, and overall psychological agility. Furthermore, A3 point out that education cultivates a sense of purpose and personal growth. This result is consistent with the view proposed by Elzohairy et al. (2024) that education is an important pathway for successful aging. A2, A7 and A10 indicate that elderly education is associated with higher levels of life satisfaction and overall well-being, which is consistent with Bianchi (2021) study. On the other hand, A3, A8 and A9 proved that elderly education enables elderly people to lead a positive and fulfilling life. Through various activities such as art classes, physical exercise, and cultural activities, elderly people can find new satisfaction, generate positive emotions, and thus improve their psychological and emotional health. This result is similar with the research findings of Zhihao et al. (2021) and Shuai et al. (2021). Education as an effective pathway for emotional regulation in the elderly. In addition, A1 and A6 Shared that education also provides opportunities for social interaction and the formation of new friendships, which are vital for combating social isolation and loneliness among older adults. This result is consistent with the research findings of Van Tienoven et al. (2020).

Although education has great potential in improving the well-being of the elderly, addressing the challenges faced by elderly education programs is crucial. A7 point out that the contradictory fact, on the one hand, resource constraints, including funding constraints and a shortage of qualified teachers, may hinder the quality and accessibility of these projects. On the other hand, the willingness of elderly people to learn is not high, and the educational content is single, which cannot meet the needs of the elderly. This result is consistent with the viewpoint of Wu et al. (2023). Wu et al. (2023) pointed out that the surveyed population generally has a lower willingness to learn in their later years and prefers learning content that is more enjoyable for the elderly. Therefore, policy makers and educators should strive to make educational opportunities more equitable, regardless of individual economic status, location, or cultural background. This can be achieved through targeted outreach and the use of technology to assist elderly people in underserved areas (Hu, 2023). A2 show that in order to meet the unique learning needs of the elderly, teaching methods and courses must be adjusted accordingly. Meanwhile, course offerings in elderly education should exhibit flexibility to cater to the diverse interests and needs of older learners. This diversity may include topics related to health and wellness, arts and culture, technology, and more (Wu et al., 2023). By diversifying course content, educational programs can better align with the preferences and goals of older adults.

CONCLUSION

The meta research findings of this study indicate that education for the elderly has a positive impact on their emotional regulation, social integration, cognitive abilities, and quality of life. Therefore, it can be considered that the well-being of the elderly can be improved by participating in educational activities, which further supports the importance of elderly education in addressing the challenges of population

aging. In addition, the study emphasizes that the curriculum of elderly education should be more personalized. By improving more comprehensive and social interactive educational methods, as well as improving policies and resources, the effectiveness of elderly education can be further enhanced to adapt to the trend of population aging. The limitation of this study is that the selected sample for this meta-synthesis study included 10 representative articles, yet it did not encompass a more extended period and all relevant articles as the research sample. The study is insufficient for a comprehensive analysis of all cases. Future research and stakeholders are advised to further investigate the influence of various types of elderly education activities on diverse circumstances and backgrounds, the correlation between the duration of education for the elderly and their well-being, the impact of active participation in elderly education on their well-being, the effect of elderly attitudes towards education on their well-being, and how to develop personalized courses based on the needs of the elderly. Moreover, there is a need to enhance more comprehensive and socially interactive elderly education methods to improve the implementation of elderly education.

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ENHANCING STUDENT ENGAGEMENT AND ACTIVE LEARNING THROUGH STUDENT PRESENTATION-BASED EFFECTIVE TEACHING (SPET) METHOD AMONG MALAYSIAN UNDERGRADUATE STUDENTS

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ABSTRACT

This study investigates the impact of the Student Presentation-Based Effective Teaching (SPET) approach on Malaysian undergraduate students. Utilising a qualitative research design, the research aims to explore how student presentations influence classroom participation and the overall learning experience in higher education. A total of 46 participants, aged 20 to 23, enrolled in a Bachelor of Arts program, participated in this study over a 14-week semester at a public university in Malaysia. Data were collected through a combination of observation, field notes, student presentations, personal communications (such as WhatsApp messages), and teacher evaluations, employing convenience sampling for its efficiency and accessibility. The findings reveal that integrating presentations into the curriculum fosters critical thinking, enhances student motivation, and facilitates a more effective learning experience. Students expressed that preparing and delivering presentations not only improved their understanding of complex topics but also encouraged them to engage in collaborative learning activities. Post-presentation tasks, such as quizzes and interactive games, further enriched the learning environment, promoting both cognitive and physical engagement.

Keywords:

Presentation-Based Effective Teaching (SPET), Student Engagement, Active participation, Undergraduate students

INTRODUCTION

In higher education, the engagement of undergraduate students in active learning processes is indispensable. A significant amount of past research has suggested that active learning techniques, can significantly enhance student participation and comprehension (e.g., Lawson et al., 2019; Arthurs & Kreager, 2017; Freeman et al., 2014). Active learning can be referred as to as an instructional approach that engages students in the learning process, encouraging them to participate actively rather than passively receiving information (Arthurs & Kreager, 2017; Martin, & Bolliger, 2018). This can involve activities like group discussions, problem-solving, case studies, and hands-on projects. The goal is to enhance critical thinking, retention, and understanding by making students more involved in their learning experiences. Students' active participation also helps solidify knowledge, making it more likely to be retained long-term, develops essential skills such as communication, teamwork, and problem-solving as well as empowers students whole learning experience.

Nevertheless, traditional pedagogical approaches seem to be the popular and common method in higher education in many countries as well as in Malaysia (Jamaluddin et al., 2023). This method often prioritises passive learning (Lawson et al., 2019), where students absorb information rather than interact with it. Especially when more technical, procedural courses with numerous concepts and terms in education, students become considerably dependent on lecturers as they often are not involved active participation. Not always, but usually the practice in higher education is where the lecturer will start the class by explaining conceptual aspects of the course topic and followed by providing examples of these concepts (Mardiningrum & Ramadhani, 2022). Usually, the lecturer then asks the students to do some exercises or activities, then the session will end with formative test. This traditional method has been criticised for promoting passive learning and rather referred as shallow learning.

One effective strategy to enhance student engagement is the incorporation of presentations as a core component of the classroom practice. At the higher education level, the ability to deliver an oral presentation is often regarded as a crucial skill for future careers (Mardiningrum & Ramadhani, 2022; Al-Nouh et al., 2015). However, tertiary-level students frequently encounter challenges in both speaking and writing in English, particularly in English as a Second Language (ESL) and English as a Foreign Language (EFL) contexts (Meganathan et al., 2024). Zhihao and Mustapha (2021) explain that university students facing academic challenges can benefit not only from additional support from teachers and peers but also from creating positive experiences that encourage active participation in and outside classroom. By actively engaging in the presentation process, students are more likely to develop a mastery of the content and gain valuable communication skills that are essential for their future careers.

LITERATURE REVIEW

An oral presentation is a planned and practiced speech that is delivered without memorisation or reading from notes, aimed at conveying information to an audience (Levin and Topping 2006) in this case, often to the lecturer and peers. Student presentations are opportunities for learners to showcase their understanding of a topic or project to their peers and instructors. Student presentations not only serve as a platform for knowledge dissemination but also encourage deeper cognitive processing, collaboration, and critical thinking. While summative assessments in higher education, such as end-of-term exams, have been conducted through written essays, typically oral presentations are part of the formative assessment. It can be both individual and group student presentations. Usually there will be a rubric given to the students to know what the expectation of the lecturer and/or the course are. Student presentation serves as a way for students to convey the material they have studied, allowing them to derive their own interpretations from the ideas of others.

In this context, numerous researchers, educators, and theorists have focused on integrating student presentations into classroom practices within higher education (e.g., Rensburg & Hagar, 2019; Tesfaye & Berhanu, 2015; Tyagi, 2022; Martella & Schneider, 2024). In 2015, Tesfaye and Berhanu conducted a study focused on improving student participation in active learning methods in Ethiopia, East Africa. Utilising a mixed-methods approach that incorporated focus group discussions, document analysis, and survey questionnaires, the researchers gathered data from 42 second-year tourism management students at a higher education institution. The results revealed that 75% of the students felt that group discussions offered them greater opportunities for active participation in class compared to presentations and demonstrations. Conversely, 25% of the students indicated a preference for presentations and demonstrations. Additionally, the study found that encouraging students to present material to their peers—especially when peer assessment was included—motivated all students to aim for excellence in their roles as presenters or demonstrators, thereby deepening their subject-specific knowledge. The study presents valuable insights into student participation in active learning methods within the Ethiopian higher education however, it does not extensively explore contextual factors that might influence students' preferences for active learning methods. A more in-depth examination of these factors could provide a fuller understanding of why group discussions were preferred by 75% of students.

Next, Rensburg and Hagar (2019) conducted classroom experiment investigated learning gains and preferences by students who served as an audience for both peer and instructor presentations in a university in the State of Minnesota, United States. Each group presentation, lasting 25 to 35 minutes, featured an interactive element, such as a game or discussion. A total of seven student presentations were interspersed with four instructor-led presentations of the same format. To measure learning gains from these interactive presentations, the same open-ended quiz question was administered both before and after each session. The findings indicate that, when provided with substantial guidance and well-defined presentation parameters, students can achieve comparable learning outcomes from their peers as they do from interactive lessons led by the instructor. This underscores the effectiveness of peer presentations in

enhancing student learning. A key strength of the study is the inclusion of interactive elements, such as games and discussions, which align with constructivist principles of active learning. Interactive learning has been shown to enhance student engagement, and the consistent use of this format in both peer-led and instructor-led presentations ensures a fair comparison of their effectiveness.

Sugeng and Suryani (2018) conducted a presentation-based learning to enhance active learning and self confidence in financial management classroom among Indonesian university students. This study aimed to identify an effective learning strategy to enhance student engagement and self-confidence in a Financial Management class through the introduction of a structured, presentation-based learning approach. Using an action research design, the study was conducted in two cycles with 120 students in the first and 110 in the second cycle. Data was collected through semi-structured questionnaires, lecturer observations, and interviews, and both qualitative and quantitative analyses were conducted. The findings showed that the approach successfully engaged students, minimized free-riding behavior, promoted self-regulated learning, and increased students' confidence in participating in class discussions. The study highlights the importance of allowing students creative freedom and accountability in their learning, contributing to improved teaching practices in higher education. The findings indicate that students exercised greater autonomy and self-regulated learning, an essential skill in higher education. This shows that structured nature of the presentations, combined with the opportunity for creative freedom, can encourage students to take ownership of their learning, preparing them for independent and lifelong learning. Interestingly, Tyagi (also see 2014: 2016: 2018: 2022) developed student presentation-based effective teaching (SPET) approach in 2014 to make student presentation activity the central element of learning challenging concepts. SPET is a structured student active teaching method that's emphasises the integration of student-led presentations (Tyagi, 2018). This method enhances student engagement and motivation by actively involving learners in the teaching process. By requiring students to present material to their peers, the SPET approach not only fosters collaborative learning but also facilitates a deeper understanding of the subject matter (Tyagi, 2022). Overall, the SPET approach serves as an effective framework for fostering a dynamic and interactive learning environment that allows the learners to take an active role in their learning through presentations, promoting a sense of ownership and accountability. The approach establishes a clear feedback mechanism involving both peers and instructors, which helps students receive constructive criticism and recognition for their efforts (Tyagi, 2016). Figure 1 shows the detailed flow chart of SPET.

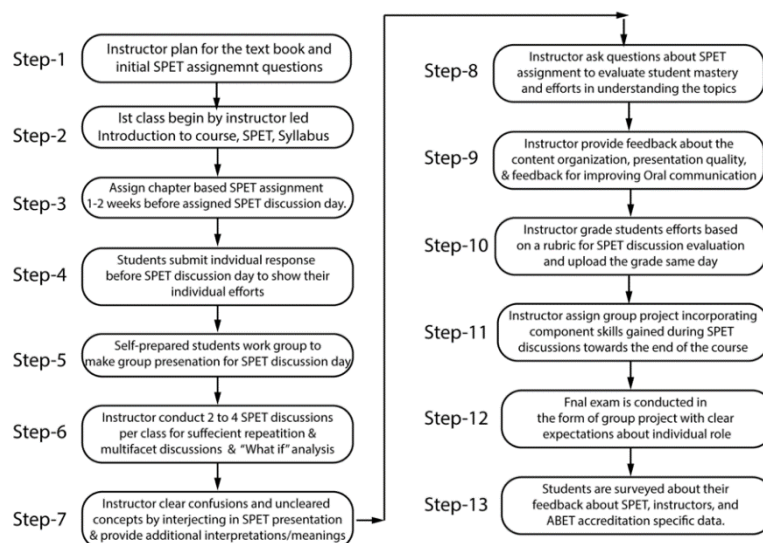


Figure 1: SPET flow Chart (Tyagi, 2022)

Tyagi (2022) integrates the SPET approach with constructivism theory, in where knowledge is actively constructed by learners through their experiences and interactions with the world, rather than passively received. Rooted in the works of theorists such as Jean Piaget and Lev Vygotsky, constructivism emphasises the importance of learners' prior knowledge and social interactions in shaping new understanding. In educational contexts, constructivist approaches advocate for learner-centered environments where students engage in problem-solving, exploration, and reflection, with teachers acting as facilitators. This theory promotes contextual, real-world learning, encouraging students to build on their existing knowledge, and has led to the development of methods such as inquiry-based and project-based learning, which emphasize active, collaborative knowledge construction (Lee & Hannafin, 2016). SPET approach connects with constructivism by emphasizing how student-led presentations foster active knowledge construction (Thomas et al., 2017). In this approach, students take on the role of presenters, engaging deeply with the material, which encourages them to explore, synthesize, and communicate their understanding. This aligns with the constructivist view that learners actively build knowledge through personal experience and reflection (Dewey et al., 1970). By presenting to peers, students are not only constructing their own understanding but also engaging in social interaction, a key component of constructivism, which helps to test and refine their ideas. It is essential to note at this point that this method enhances learning outcomes by encouraging students to actively participate, critically analyse, and collaboratively engage in the learning process, in line with constructivist principles (Piaget, 2013).

While student presentations offer numerous benefits, their implementation in higher education remains limited in many regions. When employed effectively, presentations can serve as a powerful tool for enhancing class participation. To maximise their impact, presentations should be structured to encourage students not only to design and practice their research but also to engage in collaborative efforts with peers. This could involve conducting preliminary mini group presentations prior to the main event. Furthermore, instructors might consider incorporating post-presentation activities that allow each group to reflect on their findings and experiences. Such an approach not only deepens understanding of the subject matter but also fosters a collaborative learning environment which eventually contribute to active learning. This active participation is crucial, as it fosters a dynamic learning environment where students are more likely to contribute meaningfully to discussions, engage with course materials, and develop a personal connection to the subject matter.

Furthermore, incorporating presentations into the curriculum aligns with modern educational paradigms that prioritize student-centered learning. While increased guidance from the instructor may limit opportunities for students to practice their information literacy skills and personalize their topics, it can also boost confidence in the quality of peer presentations. When students feel assured that their classmates are providing essential and accurate information, it not only enhances their learning experience but also fosters a greater appreciation for their peers' presentations (Remsburg & Hagar, 2019). Ultimately, this balance between guidance and student autonomy can lead to a more effective and enriching learning environment.

In the context of Malaysian higher education, where student engagement and participation are critical for effective learning, exploring the impact of such methods can provide valuable insights. The present study aims to investigate the impact of student presentations on active participation levels and overall engagement levels in undergraduate classrooms. By examining undergraduate students' experiences and perceptions, this research seeks to illuminate the relationship between presentation activities and student involvement, thereby contributing to the ongoing discourse on effective teaching strategies in higher education. Through this exploration, the aim is to provide insights that can inform curriculum design and pedagogical practices, ultimately enhancing the educational experience for students navigating the complexities of higher education.

Additionally, there has been very minimal exploration on SPET among Malaysian higher education institutions. Therefore, the present research highlights this gap in literature by addressing the following research question: To what extent Student Presentation-Based Effective Teaching (SPET) approach influences Malaysian undergraduate students' classroom participation? The aim involved the

fulfilment of the following research objective: The objective of this research is to examine the extent of the SPET approach influences Malaysian undergraduate students' classroom participation. Additionally, the study aims to identify the overall learning experience within the higher education context.

METHODOLOGY

Research design

This classroom investigation examines the impact of the SPET approach on Malaysian undergraduate students. A qualitative approach was applied in this study to investigate how student presentation can influence classroom participation and the overall learning experience within the higher education. In contrast to quantitative research, which emphasizes the measurement of data and the establishment of statistical relationships, qualitative research aims to explore deeper meanings, identify patterns, and gain insights (Creswell, 2015). In other words, this type of research typically involves observing and documenting behaviors, attitudes, or experiences without manipulating variables. Consequently, employing a descriptive qualitative approach facilitates a thorough understanding of Malaysian undergraduate students' classroom participation through the use of student presentations as a learning tool in higher education.

Participants

The data for the present research were collected through 14 weeks of period (one long-semester) at one of the public universities in Malaysia. There were 46 participants involved in this study. They are all between the age of 20- 23 years old studying of Bachelor of Arts (English language & linguistics) and enrolled in one of the compulsory courses (English language evolution and change) taught by the researcher herself. Convenience sampling is employed in this study due to its practicality and efficiency in data collection. As a non-probability sampling technique, it allows for the selection of participants based on their easy availability and proximity to the researcher. According to Creswell (2015), convenient sampling method is often used in qualitative research due to its ease and efficiency, allowing researchers to gather data quickly without extensive resource investment. This method is particularly beneficial in educational and clinical research settings, where engaging with participants in everyday contexts can provide valuable insights into real-world behaviors and attitudes.

Data collection method

English language evolution and change is among one of the compulsory courses for English linguistics programme at tertiary level. This course involves the undergraduate students to understand the evolution and change of English language from its Anglo-Saxon roots to its present status as the world's dominant language. Assessment coursework 60%, final examination 40%. The coursework includes tests, presentation and written assignment. Group presentation is among one of the major learning activities that is carried out during the course. In the beginning of the semester, students were told that they would require to do a group presentation of a given topic, and every group member must collaborate during the group task as well as every member must present on the topic. One of the learning outcomes of this course is for the students to be able to explain the historical development of the English language and change over the period of time which actually contribute to the 20 percentage of the overall course. They were also given a presentation rubric focusing on their mastery and acquisition of the subject matter and not so much on the language and others. Participant consent was obtained prior to the study. All real names have been omitted, and faces in the images have been blurred to protect participants identities.

At the beginning of the semester, the researcher conducted a series of lectures over a period of 2 to 3 weeks to explain the subject matter. From week 3 through week 14, student presentations were

implemented, with each presentation lasting approximately 40 minutes. In total, there were about eight groups presenting throughout the 14-week period. A key requirement of this method was that every participant within each group was expected to present, with individual marks assigned to ensure accountability. Additionally, students were tasked with designing, developing, and facilitating post-presentation activities, which included options such as mini quizzes, role plays, online games, and interactive exercises like musical chairs. The purpose of these post-presentation tasks was to foster further collaboration among classmates, encouraging them to engage actively with one another. This approach not only facilitated physical movement within the classroom but also promoted cognitive engagement in the various activities, enhancing the overall learning experience.

Each week, one student group will present for 40 minutes, followed by a 30-minute session dedicated to post-presentation tasks. Subsequently, the instructor will provide feedback on the students' presentations, fostering a reflective dialogue regarding the learning experience. The following hour and a half will involve the lecturer elaborating on the subject matter, addressing any topics that may not have been thoroughly covered during the group presentations. In this segment, the instructor will enhance the understanding of the material by introducing additional insights and facilitating activities designed to encourage student participation and knowledge sharing. These activities aim to create an interactive learning environment, allowing students to express their perspectives and engage critically with the subject matter. This structured approach not only reinforces the content delivered in the presentations but also supports collaborative learning among students, promoting a deeper comprehension of the course material. The data for the research were collected through various forms; observation, field notes, pictures, students' presentation aids (e.g., Canva, PPT), personal text messages, emails, WhatsApp messages, teacher evaluation form, student-student interaction, teachers-student interactions, and figures. Simply put, more than one data source was needed to support the assumptions of the research results.

Data analysis

The data analysis commenced with the transcription of interactions between students and teachers, both in and out of the classroom, as well as observations made during these interactions. The researcher focused on selecting information-rich exchanges, paying particular attention to students' responses and reactions to the SPET approach. These interactions were transcribed into line-by-line excerpts accompanied by the researcher's initial notes. The excerpts were carefully examined, and the information was reorganized and categorized to identify emerging patterns. In addition to the interactions, other sources such as pictures, teacher feedback forms, PowerPoint or Canva slides, field notes from observations, and the teacher evaluation form were also analysed. Findings that reflected any of the identified themes were categorised accordingly to support the conclusions drawn from the study. In this study, thematic analysis was employed to examine participants' spoken responses, aiming to understand and interpret their meanings by identifying patterns within the data. This approach is especially valuable for research projects focused on uncovering themes and concepts within qualitative data. The process involved steps such as coding the data, organizing categories, identifying themes, and reporting conclusions to address the research questions (Braun & Clarke, 2012).

RESULTS & DISCUSSION

The data collected revealed four main themes regarding the use of students' group presentation as a tool for learning and to create an engaging classroom environment. The identified four distinct themes: i) promotes critical thinking, ii) motivated and highly interested, and iii) effective and easier learning. The results of each of these themes are detailed in the following section.

Promotes Critical thinking

The integration of presentations into classroom activities plays a significant role in fostering critical thinking among students. Critical thinking in classroom have been studied widely in the past. Studies are suggesting that it can enhance student's understanding of the material by encouraging them to analyse and question rather than just memorise the facts (Halpern, 2013). This leads to a more nuanced grasp of concepts and better retention of information. Besides, when students are allowed and then courage to be critical thinkers in class, this leads them to be independent thinker as well as creative when participating in class activities, completing a task, or creating a framework (Lin et al., 2018). Developing critical thinking skills equips students to tackle complex problems more effectively. They learn to break down problems, evaluate solutions, and make informed decisions, which is valuable both in academics and in real-world situations. This finding is consistent with constructivism theory, where learners are viewed as active participants in their own learning process, engaging with their environment, constructing knowledge through experiences, and developing critical thinking skills that enable them to connect theoretical concepts with practical applications (Lee & Hannafin, 2016; Piaget, 2013). The feedback collected from students highlights various ways in which the process of preparing and delivering presentations enhances their analytical and evaluative skills. Following are the experts from the student's feedback.

From presenting, I learn how to get information's on given topic, on top of that I had to find better ways to explain it to my friends in class (S1)

It helps with creativity as we need to prepare for the presentation as well as the follow up activity slash game. (S2)

It helps us to improve our researching skills and our critical thinking skill since we have to prepare plan and design our presentation. (S3)

It promotes our research skills as we need to do thorough research on the subject. (S4)

One key benefit noted is the development of research and explanatory skills. *S1* reflects, how the process of presenting encourages students to gather and synthesise information effectively and then communicate it clearly, thus honing their ability to analyse and articulate complex ideas. This process aligns with findings from educational research, which suggests that presenting information requires students to engage deeply with the material, fostering higher-order thinking skills such as analysis and synthesis (Ganguli, 2024).

Other than that, *S4* explains that presentation tend to help her to improve researching skill as she need to find out some information prior to their presentation, and this helps her to not only best understand the subject of matter but also developed their researching skill. Meanwhile as mentioned by *S2*, student presentation also helps in boosting their creativity; especially in designing the Power Point Slides (PPT) and/or Canva as well as in creating a simple post-presentation activity/game. Sample of student's presentation canvas are presented below. Past research supports that creativity in presentation design enhances problem-solving and critical thinking skills, in fact Runco and Acar (2012) asserts that engaging in creative tasks promotes cognitive flexibility and innovation.

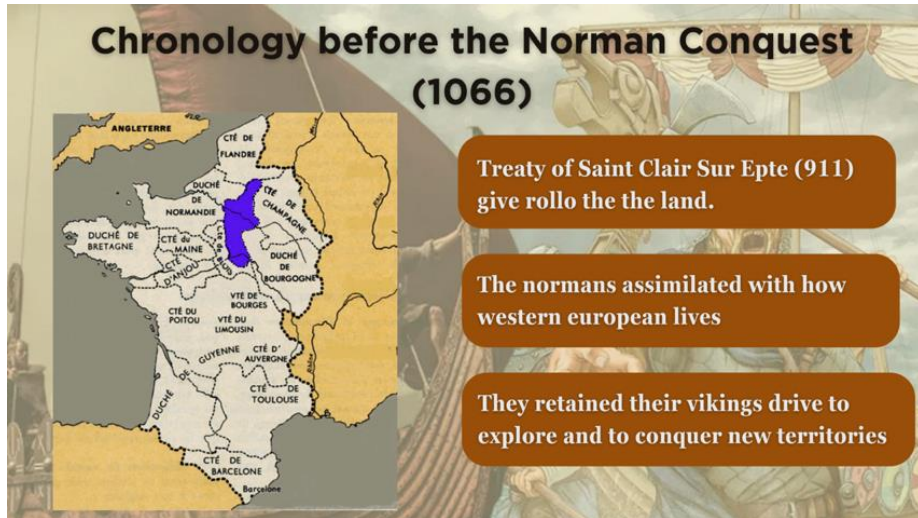


Figure 2: Sample student’s presentation on Norman Conquest using PPT

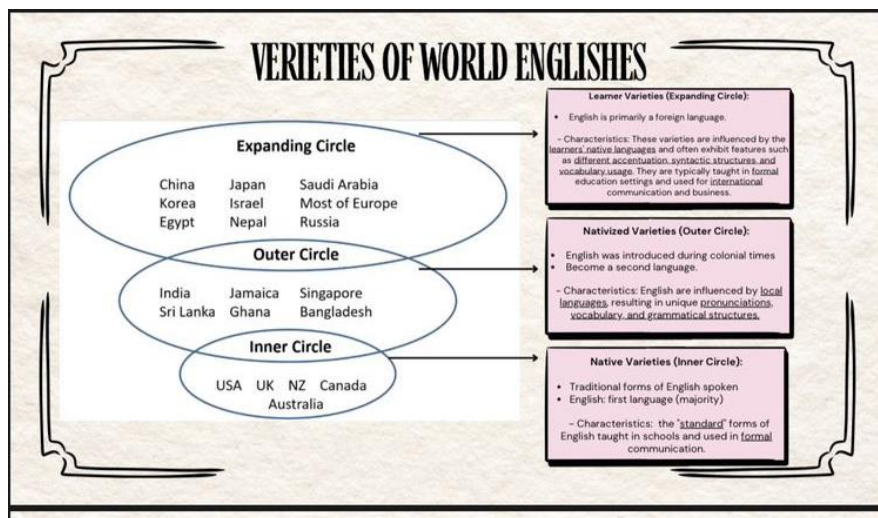


Figure 3: Student’s presentation on Varieties of World Englishes using Canva

These are among a few chosen slides from the collection of students presentation students (the researcher is not able to attach the complete presentation slides in this paper). It is essential to note here that from observation, it is evident that the participants of this research over the period of time get curious, excited and creative to prepare the presentation slides and the post activity. In fact, there was a slight pressure in them to prepare an interesting and eye-catching slide. Consequently, a few students also tried to include other visual aids (e.g., you tube videos, songs, QR codes) for presentation and online games and quizzes for the post presentation activity. Overall, this led to an enhanced learning experience that fostered critical thinking among the students. As they engaged with various multimedia elements and worked collaboratively, they were encouraged to analyse information more deeply and consider different perspectives. The process of designing their presentations required them to evaluate content critically,

synthesize ideas, and articulate their thoughts clearly. Moreover, the interactive post-presentation activities prompted them to apply their knowledge in practical ways, reinforcing their understanding and stimulating further inquiry. This approach not only improved their presentation skills but also cultivated a mindset geared toward exploration and innovation, essential components of critical thinking.

Motivated and highly interested

In the ever-evolving landscape of education, the effectiveness of a teaching approach is reflected in its capacity to foster meaningful learning experiences and measurable growth among students. Drawing on Vygotsky's Zone of Proximal Development (ZPD), the data collected from student feedback highlights the positive impact of presentation-based learning on student engagement and enthusiasm. This approach not only supports students in developing their skills with the guidance of peers and instructors but also encourages collaborative interactions that enhance understanding and retention of knowledge. Following are the experts taken from students WhatsApp feedback and teaching evaluation.

From my classmates' presentations, I get to learn the topics in an interesting way and while participating in games after the presentation, is way better than just sitting and listening to lecturer. (S5)

The whole experience of the course (learning through presentation) was so fun. This experience has been so positive that I am seriously considering on pursuing a master's on this course. (S6)

If you get X as your lecturer prepare to have fun. She is the best professor I could ask for and honestly, I'm sad that I won't be having any classes with her after this. I am so happy to have met a professor like her and I enjoyed a class so much. So far this is the best class for this semester. (S7)

One of the best fun classes so far for this semester. (S8)

Enjoyed every bit of the activity, from presentation to the activities and games that followed by the presentation. (S9)

It was a fun learning experience that helps us to remember the information better. (S10)

The data shows that the students repeated used the words like 'fun', 'interested' and 'enjoy' expressing how they feel about doing presentation as part of the class activities. They also referred positively towards the post presentation activities (e.g., language games) that were carried out (e.g., language games). Another evident of the students highly enjoyed the presentations was when they compared it to be better than the other subjects/ courses they took in the same semester. The comments reflect how presentations allow students to learn from each other in an interactive environment. Vygotsky (1978) emphasized that learners benefit from guidance and support from peers and instructors, which helps them progress through their ZPD. The collaborative aspect of presentations likely provided scaffolding, enabling students to tackle complex concepts that they might not have been able to grasp independently. This is suggesting that using presentation as a learning activity in class, seems to be elevating the student's interest on the subject matter, which eventually increase their motivation to learn. In fact, S6 stated that she is even seriously considering herself to pursue a master's degree on historical language. This sentiment aligns with research indicating that interactive and participatory learning methods can increase student motivation and interest (Althof, 2024; Freeman et al., 2014; Hernández-de-Menéndez et al., 2019; Sugeng & Suryani, 2018).

The impact of enthusiastic and engaging teaching on student motivation is also evident. As remarked by S7, "If you get X as your lecturer, prepare to have fun. She is the best professor I could ask for and honestly, I'm sad that I won't be having any classes with her after this. I am so happy to have met a professor like her and I enjoyed a class so much. So far this is the best class for this semester." This feedback underscores the importance of an instructor's role in creating an engaging learning environment and how it contributes to student motivation and satisfaction (Pike & Kuh, 2005).

Furthermore, the enthusiasm for the course was echoed by another student who described it as "one of the best fun classes so far for this semester," and another who enjoyed "every bit of the activity, from presentation to the activities and games that followed by the presentation." These comments reflect a broader trend where interactive and participatory elements not only enhance enjoyment but also deepen interest in the subject matter (Althof, 2024). In fact, Yu and Singh (2024) suggest that a well-structured classroom environment and effective teaching methods play a significant role in boosting students' enthusiasm for learning.

Through observation it was also noticed that during the initial stage of the semester where the teaching approach was more to teacher centered method, the students were observed to be only passively engaged in classroom. The research noticed that the students often not physically, or cognitively engaged during the lesson. They tend to listen to the lecture and carry one with the learning activity thereafter. In fact, there was no chance to engage among themselves or to move around the classroom. Therefore, the overall environment of the class was very dull and seemingly less motivated.



Figure 4: Post Presentation Activity (Language Monopoly Game)



Figure 5: Post Presentation Activity Role-play

However, as seen on Figure 3 and 4, doing presentation and participating in the post presentation activities, the students seemed to enjoy the learning process as they get to work with others, and they get to be actively involved with the lesson/subject matter. By the end of the semesters, the student's interest on the subject matter as well as their motivation to learn increased over the time. Student engagement in classroom not only boosts their satisfaction, but also heightens motivation to learn thus, diminishes their feelings of isolation, and leads to better performance (Althof, 2024; Martin & Bolliger, 2018).

Effective and Easier Learning

One of the prominent themes that emerged from the data is how presentations facilitate more effective and easier learning for the students. The integration of student presentations into the learning process appears to significantly enhance students' understanding and retention of complex material. Following are the experts taken from students spoken and written feedback.

I think doing a presentation about a topic is a good way to understand about a topic better. (S11)

I am not a history person because I find it very hard to remember details. Since language evolution class involves a lot of historical details, dates and historical figures, I find that learning this subject through student presentation is one of the best ways to do so. It actually helped me to even remember the littlest detail. (S12)

I think using group presentation is very impactful way of letting the students to understand the topic prior to the lecture itself. (S13)

The course was made much easier for us with the group presentations. (S14)

The method used in language evolution course, were very helpful and engaging. (S15)

It was a fun learning experience that helps us to remember the information better. (S16)

Our lecturer always engage students to do hands on activities like presentation that help us better understand the topics and much easier way of doing it. (S17)

Several students highlighted those presentations are an effective method for gaining a deeper understanding of the topic. As *S11* noted, the act of preparing and presenting material enables students to engage more thoroughly with the content, leading to improved comprehension. In courses with challenging content, such as those involving extensive historical details, presentations can offer a valuable alternative to traditional learning methods. For instance, *S12* stated "*I am not a history person because I find it very hard to remember details. Since language evolution class involves a lot of historical details, dates, and historical figures, I find that learning this subject through student presentation is one of the best ways to do so.*" This student's experience underscores how presentations can make dense material more manageable and memorable, turning perceived difficulties into opportunities for active learning.

Group presentations, in particular, were cited as a beneficial approach. One participant observed, by engaging in group work, students not only prepare themselves but also collaboratively explore the topic, which can enhance their collective understanding before formal instruction occurs. Moreover, students appreciated the engagement strategies employed by their lecturer. As *S17* noted, "*Our lecturer (X) always engages students to do hands-on activities like presentation that help us better understand the topics and much easier way of doing it.*" This approach aligns with findings (Tyagi, 2022; Thomas et al., 2017). those hands-on activities, including presentations, foster deeper engagement and facilitate learning in a more interactive and enjoyable manner.

CONCLUSION

The findings of this study underscore the significant impact of the Student Presentation-Based Effective Teaching (SPET) approach on enhancing student active participation, critical thinking, motivation level, student engagement and overall learning experiences. Through the integration of presentations as a core instructional strategy, students not only engaged more deeply with the subject matter but also developed essential skills in research, creativity, and critical analysis. This is in line with the principles of constructivism theory as proposed by Piaget, where learners actively construct their own understanding and knowledge of the world through experiences and reflections. By engaging in presentation-based learning, students are not merely passive recipients of information; instead, they take an active role in their education. This hands-on approach allows them to explore concepts more deeply, encouraging them to connect new knowledge with their existing cognitive frameworks (Piaget, 2013). As they present their findings, collaborate with peers, and engage in discussions, they enhance their cognitive abilities and foster a deeper comprehension of the material. Ultimately, this aligns with Piaget's belief that meaningful learning occurs when learners interact with their environment and construct knowledge through active engagement and inquiry.

The qualitative feedback from participants highlights that SPET method transforms the learning environment, fostering a sense of curiosity and enthusiasm that contrasts sharply with traditional, lecture-based approaches. Students reported that the process of preparing and delivering presentations not only helped them understand complex historical details more effectively but also increased their motivation and interest in the subject. Vygotsky's theory suggests that a positive learning environment, where students feel supported and engaged, enhances motivation and the desire to learn. The incorporation of interactive post-presentation activities further contributed to a collaborative atmosphere, allowing students to work together, engage physically, and apply their knowledge in practical settings (Vygotsky, 1970). This shift from passive to active learning resulted in improved retention of information and a

deeper appreciation for the material. The results reveal that students find the learning experience fun and effective, suggesting that they are actively constructing their understanding through participation in presentations and subsequent activities. This aligns with the notion that knowledge is built collaboratively rather than through passive absorption.

Moreover, the instructor's role in creating an engaging learning environment was crucial, as evidenced by students' positive feedback regarding their experiences in the course. The alignment of presentation-based learning with contemporary educational paradigms emphasises the importance of interactive, student-centered approaches in fostering meaningful learning experiences. Overall, the SPET approach not only enhances academic outcomes but also cultivates a mindset geared toward exploration and innovation. As educational practices continue to evolve, the findings from this study advocate for the broader adoption of presentation-based strategies to enrich learning experiences and better prepare students for the complexities of their academic and professional futures.

Based on the findings of the present study, educators and policymakers are encouraged to adopt the SPET approach as one of the core instructional strategies across various subjects in higher education. This can be achieved by incorporating presentation-based learning and interactive post-presentation activities that promote collaboration and active engagement among the tertiary level students. It is important to note that educators should take on a facilitator role, providing guidance and constructive feedback while creating a supportive classroom atmosphere. Additionally, integrating technology and multimedia tools can further enhance creativity and interest among students of the topic/course. Meanwhile, policymakers should advocate for educational policies that support innovative teaching practices, including funding for teacher training, funding and other resources. Besides, ongoing research into the long-term effects of presentation-based methods on student engagement and effectiveness is also essential for informing future educational strategies. By implementing these recommendations, we can foster a more engaging learning environment that enhances student participation, critical thinking, and overall academic success.

AUTHOR BIOGRAPHY

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CHALLENGES IN GEOGRAPHICAL ORIGIN IDENTIFICATION OF PANAX NOTOGINSENG

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ABSTRACT

Geographical origin identification is critical for ensuring the quality, authenticity, and safety of *Panax notoginseng*, a cornerstone of traditional Chinese medicine. This study addresses key challenges in this domain, including imbalanced data distribution, complex pre-processing requirements, counterfeit product proliferation, and the trade-off between model flexibility and interpretability. Three primary values of origin identification are emphasized: safeguarding consumer health and rights, enhancing herbal material quality, and preserving traditional herbal knowledge. Proposed solutions include constructing balanced datasets, optimizing pre-processing techniques, integrating advanced anti-counterfeit mechanisms, and developing interpretable models. Empirical validation demonstrates that these measures significantly improve prediction accuracy, transparency, and practical applicability. Additionally, the study highlights the importance of collaboration between academia, industry, and regulatory bodies to establish standardized practices for data collection, model evaluation, and product traceability. This research provides a comprehensive framework for geographical origin identification, fostering trust in herbal products, preserving cultural heritage, and advancing sustainable practices in the herbal industry.

Keywords:

Geographical origin identification, Panax notoginseng, herbal quality, traditional herbal knowledge, consumer rights.

INTRODUCTION

The accurate determination of the geographical origin of botanical materials has gained increasing attention due to its significant implications for quality assurance (Cui et al., 2022; Li et al., 2023), consumer safety (Liu et al., 2023; Yue et al., 2022), and the preservation of traditional knowledge (Gao et al., 2022; Yang et al., 2019). Geographical environments profoundly influence the growth conditions (Liu et al., 2023), chemical composition (Gao et al., 2022; H. Liu et al., 2020; Z. Yang et al., 2018), and therapeutic properties of medicinal plants (Chan et al., 2019; Liu et al., 2022; Pan et al., 2016). Among these, *Panax notoginseng*—a highly valued herb in traditional Chinese medicine—stands out as particularly sensitive to environmental variations.

Known as "Sanqi," *Panax notoginseng* has been historically used for its reputed benefits in enhancing blood circulation, alleviating pain, and supporting cardiovascular health (Gu et al., 2024). Its diverse therapeutic applications have driven high demand in herbal formulations and medical products (Cui et al., 2022). However, the authenticity and quality of *Panax notoginseng* face challenges due to the proliferation of counterfeit and substandard products (Chan et al., 2019; Pan et al., 2016).

Geographical origin plays a pivotal role in shaping the chemical composition and therapeutic efficacy of *Panax notoginseng* (Liu et al., 2020; Zhu et al., 2014). Variations in environmental conditions across regions result in diverse profiles of bioactive compounds, directly influencing the herb's medicinal properties. Consequently, identifying the geographical origin accurately is critical for ensuring product efficacy, quality, and consumer safety (H. Li et al., 2024).

This study aims to provide a comprehensive exploration of the methodologies and challenges associated with determining the geographical origin of *Panax notoginseng*. By addressing these complexities, this research underscores the significance of geographical traceability in traditional medicine, consumer protection, and the botanical trade. Subsequent sections discuss the importance of

origin identification, key challenges, and innovative approaches to overcome these obstacles (Dong et al., 2020; Ji et al., 2023).

IMPORTANCE OF GEOGRAPHICAL ORIGIN IDENTIFICATION

Accurate identification of the geographical origin of *Panax notoginseng* holds profound importance beyond its botanical context, impacting the quality of herbal materials, the preservation of traditional knowledge, and the protection of consumer health and rights. The intricate relationship between the plant and its growing environment underscores the need for a comprehensive understanding of its origin. This understanding serves as the foundation for ensuring product safety, safeguarding cultural heritage, and empowering consumers with informed choices (Ji, et al., 2022; Zhang & Rao, 2007).

Ensuring Herbal Material Quality and Safety

A primary objective of identifying the geographical origin of *Panax notoginseng* is to ensure the quality and safety of herbal materials (Peng et al., 2021; Tian et al., 2021). The unique environmental conditions of different regions—such as soil mineral content, precipitation, temperature, and altitude—play a critical role in shaping the plant's chemical composition, therapeutic properties, and overall quality. This dynamic interplay between the plant and its environment is fundamental to its medicinal value.

However, this close relationship also exposes vulnerabilities. The same environment that enhances the plant's bioactive profile can also introduce contaminants, such as heavy metals, pesticides, and pollutants, which compromise both therapeutic efficacy and consumer safety (Chen et al., 2018; Yue et al., 2022). These risks highlight the importance of tracing the plant's geographical origin.

Accurate determination of the geographical origin provides a robust mechanism to mitigate such risks. By pinpointing the regions of cultivation, targeted monitoring and stringent quality control measures can be implemented. This capability enables regulatory authorities, manufacturers, and consumers to make informed decisions regarding the sourcing and use of herbal materials (Li et al., 2018; Xinyue et al., 2021). Ensuring that products are sourced from uncontaminated regions not only safeguards consumer health but also enhances market integrity, builds consumer trust, and supports the sustainable development of the herbal industry.

Preserving and Advancing Traditional Herbal Knowledge

Accurate identification of the geographical origin of *Panax notoginseng* extends beyond its chemical composition and therapeutic efficacy, holding profound implications for the preservation and advancement of traditional herbal knowledge (Xinyue et al., 2021). Indigenous communities, deeply connected to their environments, have cultivated a rich understanding of local medicinal plants over generations. This knowledge encompasses not only the plants' properties but also their interactions with the specific ecosystems in which they flourish.

Geographical origin identification acts as a bridge to reconnect with and revitalize traditional herbal wisdom (Yang et al., 2018). It reaffirms the intrinsic link between plants, their environments, and the cultural practices surrounding their use. By recognizing the distinct characteristics of plants from different regions, we honor the insights of indigenous healers and preserve the invaluable traditional knowledge they have passed down. This process enriches our understanding of historical practices and highlights the intricate interplay between cultural heritage and natural resources.

Furthermore, integrating traditional knowledge with modern scientific methodologies offers significant opportunities for innovation. The combination of time-tested practices and contemporary research can validate traditional applications while uncovering new possibilities for exploration (Bai et

al., 2021). This fusion of heritage and science not only revitalizes the field of herbal medicine but also supports the sustainable development and dissemination of traditional healing practices.

Safeguarding Consumer Health and Rights

In an era of heightened awareness around product authenticity and consumer rights, accurately determining the geographical origin of *Panax notoginseng* is critical for safeguarding consumer health and trust (ChunYan et al., 2016).. The proliferation of counterfeit and adulterated herbal products has not only undermined public confidence but also posed serious health risks. Misleading information about the origin of herbal products exposes consumers to uncertain compositions, potentially causing adverse reactions or rendering the products ineffective.

Transparent origin identification mitigates these risks by providing accurate information that empowers consumers to make informed decisions aligned with their health goals and preferences (Lin et al., 2022; Yang et al., 2019).. Such transparency fosters consumer confidence, enabling individuals to take proactive control of their well-being.

Additionally, accurate labeling and origin verification promote accountability within the herbal industry (Yang et al., 2018). These practices deter unethical behaviors that compromise product integrity and erode consumer trust. By emphasizing transparency, ethical sourcing, and rigorous quality assurance, origin identification establishes a foundation of trust that benefits consumers, manufacturers, and the industry as a whole (S. Zhang et al., 2023a).

In summary, the accurate determination of geographical origin extends beyond scientific inquiry into broader realms of quality assurance, cultural preservation, consumer empowerment, and sustainable industry growth. This interconnected approach weaves together plants, environments, cultures, and individuals, creating a tapestry that harmonizes health, heritage, and trust.

CHALLENGES AND ISSUES

The geographical origin identification of *Panax notoginseng* is a complex and multifaceted task, presenting numerous challenges across various dimensions (Ji, et al., 2022; Li, 2017; Liu et al., 2022; Zhang et al., 2022). These challenges include data availability and quality, methodological and modeling complexities, regulatory frameworks, and the need for seamless integration within the industry. Overcoming these obstacles is essential to develop accurate, reliable, and practical methods for origin identification.

Imbalance in Sample Data Distribution

One of the primary challenges in geographical origin identification lies in the inherent imbalance in sample data distribution. Real-world datasets often exhibit significant disparities in sample representation across geographic regions (Liang et al., 2021; Zhou et al., 2020). Regions with higher production volumes tend to dominate datasets, leading to biased model performance that favors majority classes while neglecting underrepresented regions. This imbalance undermines the model's ability to accurately classify minority classes.

To address this issue, techniques such as data augmentation, oversampling, and under sampling can be employed to balance representation. Advanced methods, including generative adversarial networks (GANs) and variational autoencoders, can generate synthetic data to enhance minority class representation. These approaches ensure more comprehensive and unbiased model performance across all geographic origins.

Complexity of Data Pre-processing

Data pre-processing is a critical yet challenging step due to the influence of diverse environmental factors, sensor characteristics, and collection methodologies (Liu et al., 2016; Wang et al., 2006). Raw datasets often contain noise, inconsistencies, and heterogeneity, complicating analysis.

Effective pre-processing requires advanced techniques such as noise reduction through filtering, denoising autoencoders, and wavelet transformations. Dimensionality reduction methods, including principal component analysis (PCA) and t-distributed stochastic neighbor embedding (t-SNE), aid in retaining essential features while simplifying the dataset. These strategies enhance model robustness and improve prediction accuracy.

Combating Counterfeit Products

The proliferation of counterfeit *Panax notoginseng* products poses a threat to consumer trust and industry integrity (H. Li et al., 2024; C. Liu et al., 2023b). Counterfeit goods often mimic authentic geographical origins, misleading consumers and harming legitimate producers.

Advanced anti-counterfeiting technologies such as QR codes, RFID tags, and blockchain-based authentication systems can secure supply chains by providing transparent, traceable information about product origins (Yang et al., 2022). These tools strengthen consumer confidence, protect brand reputation, and enhance the credibility of the herbal industry.

Model Flexibility and Generalization

Developing effective models for origin identification requires balancing flexibility and generalization (Zhang et al., 2022). Highly flexible models, such as deep neural networks, can capture complex patterns but risk overfitting, while overly generalized models may fail to discern subtle regional differences.

To strike this balance, regularization techniques such as dropout, L1/L2 regularization, and early stopping can prevent overfitting. Ensemble learning methods, which aggregate predictions from multiple models, further enhance generalization. Cross-validation ensures robust performance by validating models on diverse subsets of data.

Balancing Interpretability and Regulatory Requirements

High-performing machine learning models often lack transparency, posing challenges for regulatory compliance and accountability (Yang et al., 2018). Regulatory bodies require interpretable models to ensure their decisions can be explained and justified.

Hybrid approaches that combine predictive accuracy with interpretability, such as local interpretable model-agnostic explanations (LIME) and Shapley additive explanations (SHAP), can provide insights into model behavior (Li et al., 2017; Liu et al., 2023). These techniques facilitate compliance with industry standards while maintaining prediction accuracy.

Integration within Industry Ecosystem

Effective integration of geographical origin identification within the herbal industry ecosystem requires collaboration among diverse stakeholders, including data scientists, manufacturers, and regulatory bodies (Li et al., 2017). Bridging gaps in expertise and priorities necessitates open communication, shared understanding, and streamlined workflows.

Integration must also address ethical and social dimensions, such as fair trade, sustainable sourcing, and ethical harvesting practices. Collaborative efforts can ensure that the industry aligns technological advancements with economic and social goals.

Standardization and Benchmarking

Establishing standardized protocols and benchmarks is crucial for ensuring the reliability and comparability of origin identification methods (HuiLing et al., 2019). Consistency in data collection, pre-processing, feature extraction, and evaluation methodologies is essential for reproducibility.

Collaboration among academia, industry, and regulatory bodies is needed to define and update these standards, balancing innovation with reliability. Such efforts provide a foundation for advancing the field while maintaining methodological rigor.

SOLUTIONS AND METHODS

The complex challenges associated with the geographical origin identification of *Panax notoginseng* require innovative, interdisciplinary, and standardized approaches (Li et al., 2023; Zhang et al., 2023). This section outlines key solutions across data management, advanced modeling, anti-counterfeiting measures, and industry collaboration.

Building a Balanced Geographic Sample Dataset

To address imbalanced data distribution, constructing a balanced dataset is essential. This involves augmenting underrepresented regions using techniques like oversampling, under sampling, and Synthetic Minority Over-Sampling Technique (SMOTE) to create synthetic samples while maintaining data integrity. Collaboration with botanical experts ensures the inclusion of diverse samples reflecting the true distribution of *Panax notoginseng*.

Strategies such as Borderline-SMOTE further enhance sample diversity, improving the model's ability to predict origins for less-represented regions and mitigating biases that often favor majority classes.

Enhancing Data Preprocessing Techniques

Effective pre-processing is crucial to manage noise, heterogeneity, and inconsistencies in raw data. Techniques like denoising autoencoders, wavelet transformations, and Principal Component Analysis (PCA) enhance data quality and reduce noise. Dimensionality reduction methods such as t-distributed Stochastic Neighbor Embedding (t-SNE) help identify informative features while retaining essential patterns.

Incorporating domain-specific knowledge during pre-processing further refines data quality, ensuring robust and interpretable origin identification models.

Strengthening Anti-Counterfeit Mechanisms

Counterfeit *Panax notoginseng* products threaten consumer trust and industry credibility. Advanced anti-counterfeiting technologies, including QR codes, RFID tags, and blockchain systems, provide end-to-end traceability. These tools ensure transparency by documenting a product's journey from cultivation to consumption.

Blockchain's decentralized and immutable framework secures supply chains, enabling regulatory bodies and consumers to verify product authenticity and quality. Collaborative efforts among manufacturers, regulators, and technology providers are vital for implementing these measures effectively.

Enhancing Model Flexibility and Generalization Strategies

Balancing model flexibility with generalization is critical to avoid overfitting while capturing geographic nuances. Regularization techniques, such as dropout and L1/L2 regularization, prevent overfitting by constraining model complexity. Ensemble methods, such as Random Forest and Gradient Boosting, combine predictions from multiple models, enhancing robustness and stability.

Cross-validation strategies further ensure that models perform reliably on unseen data, enabling a balance between complexity and general applicability in origin identification.

Developing and Applying Interpretability Models

Transparent and interpretable models are essential to meet regulatory requirements and build trust. Techniques like Local Interpretable Model-agnostic Explanations (LIME) and SHapley Additive exPlanations (SHAP) provide insights into how input features influence model predictions.

These methods allow researchers to identify potential biases, validate model decisions, and ensure accountability. By integrating interpretability into model design, the field achieves a balance between high predictive performance and regulatory compliance.

Fostering Industry-Regulatory Collaboration

Effective integration of geographical origin identification within the herbal industry requires collaboration among stakeholders, including researchers, industry leaders, and regulators. Interdisciplinary workshops and communication channels foster shared understanding and streamline practices.

Collaborative platforms promote knowledge exchange on challenges, innovations, and best practices. By addressing economic, ethical, and sustainability considerations, such partnerships ensure that geographical origin identification aligns with broader industry goals.

Establishing Data Collection, Pre-processing, and Evaluation Standards

Standardized protocols for data collection, pre-processing, and evaluation are crucial for consistency and comparability across studies. Collaborative initiatives involving academia, industry, and regulatory bodies can define adaptive standards to accommodate technological advancements while maintaining rigor.

Guidelines for data collection should specify sample sizes, geographic diversity, and quality metrics. Preprocessing standards should address noise reduction, feature engineering, and outlier management. Evaluation protocols must outline performance metrics and cross-validation practices, ensuring reliable and reproducible results.

RESULTS AND DISCUSSION

The implementation of the proposed solutions and methods for geographical origin identification of *Panax notoginseng* has yielded substantial results. This section evaluates these outcomes through comparative analyses, real-world case studies, and the validation of practical effectiveness, providing a comprehensive assessment of the solutions' impact.

Comparative Analysis of Different Methods and Effectiveness Evaluation

A key component of this study involves evaluating the performance of various methods for geographical origin identification. Machine learning algorithms, including Random Forest, Support Vector Machines (SVM), and Convolutional Neural Networks (CNN), were applied, with performance assessed using metrics such as accuracy, precision, recall, F1-score, and AUC-ROC.

The results indicate that a holistic approach—integrating balanced datasets, advanced pre-processing techniques, and interpretable models—consistently outperforms individual methods. Traditional algorithms such as SVM and Random Forest demonstrate robust performance, particularly in handling moderately complex datasets. However, CNNs excel in capturing intricate patterns related to geographical variations.

Furthermore, ensemble methods combining these approaches mitigate biases and achieve high predictive accuracy. This analysis highlights the strengths and limitations of each technique, offering critical insights for selecting optimal strategies tailored to specific application scenarios. The effectiveness of ensemble methods, in particular, underscores their potential as a preferred choice for practical applications.

Case Analysis of Model Application

To demonstrate the practical utility of the proposed solutions, a case study was conducted using real-world samples of *Panax notoginseng* from diverse geographic regions with varied cultivation practices. The trained models were applied to this dataset, producing results that validate their predictive capabilities.

For instance, a sample with an uncertain origin was analyzed using the ensemble model, which generated a probability distribution across possible origins. The model accurately assigned the sample to a specific region with a high degree of confidence, showcasing its ability to resolve origin ambiguity.

This case study underscores the practical applicability of the solutions in addressing real-world challenges. By accurately predicting sample origins, the proposed framework enhances the precision and reliability of geographical origin identification.

Validation of Solution Practicality

The practicality of the proposed solutions was validated through collaborations with industry partners and regulatory bodies. Anti-counterfeit mechanisms, including blockchain-based traceability systems, were successfully implemented, enabling stakeholders to monitor the journey of *Panax notoginseng* products from cultivation to consumers.

Feedback from industry stakeholders confirms a significant reduction in counterfeit incidents and an increase in consumer trust. Manufacturers report streamlined operations resulting from standardized data collection and pre-processing practices. Regulatory bodies express satisfaction with the models' traceability and interpretability, aligning with oversight requirements.

These validations highlight the transformative potential of the proposed solutions, extending beyond geographical origin identification to fostering collaboration, accountability, and sustainability in the herbal industry.

Comprehensive Framework and Future Implications

The results presented in this section underscore the feasibility and effectiveness of the proposed framework, combining balanced datasets, advanced pre-processing, interpretable models, and industry-regulatory collaboration. This integrated approach not only addresses the technical challenges of origin identification but also establishes a foundation for broader adoption within the industry.

The demonstrated reliability and practicality inspire confidence in the proposed solutions and lay the groundwork for future advancements in geographical origin identification. These outcomes provide a model for other herbal resources, contributing to the overall integrity and sustainability of the herbal industry.

CONCLUSION

This study explores the multifaceted challenges and opportunities in the geographical origin identification of *Panax notoginseng*, a critical aspect of herbal authentication. The significance of this research extends beyond botanical science, impacting traditional medicine, consumer safety, and industry integrity. Here, we summarize the key findings, emphasize the importance of the proposed solutions, and outline directions for future advancements.

Summary of Key Challenges

The journey toward effective origin identification is marked by significant challenges, including the imbalance in sample data distribution, complexities in data pre-processing, the threat of counterfeit products, model flexibility and interpretability issues, and the need for industry-wide standardization. These hurdles, while substantial, also present opportunities for innovation, driving the development of solutions that bridge scientific rigor and practical application.

Importance of Proposed Solutions

The solutions proposed in this study are practical tools designed to ensure the authenticity, quality, and safety of *Panax notoginseng* products. Key contributions include:

- **Balanced Datasets:** Addressing data imbalance through strategic augmentation and advanced sampling techniques.
- **Advanced Data Pre-processing:** Mitigating noise and inconsistencies to enhance model accuracy.
- **Anti-Counterfeit Mechanisms:** Leveraging blockchain, RFID, and QR codes to fortify product traceability.
- **Model Optimization:** Enhancing flexibility and generalization while maintaining interpretability.
- **Collaboration and Standardization:** Bridging academia, industry, and regulatory bodies to harmonize practices and establish data standards.

These innovations reflect a holistic approach that addresses individual challenges while integrating solutions to amplify their collective impact. This synergy fosters reliability and practicality across the herbal value chain, building trust among stakeholders and advancing the field of origin identification.

Future Directions

Looking forward, several promising directions emerge for the continued evolution of geographical origin identification:

- **Advanced Analytical Techniques:** Integrating hyperspectral imaging and metabolomics to detect subtle geographic variations in chemical composition.
- **Expanded Blockchain Applications:** Developing robust, immutable traceability systems to enhance transparency and consumer trust.
- **Global Standardization:** Establishing international protocols for data collection, pre-processing, model evaluation, and labeling to unify practices across regions.
- **Sustained Collaboration:** Fostering deeper partnerships between academia, industry, and regulatory authorities to anticipate and counteract emerging challenges.

By embracing these directions, the field can continue to innovate and adapt, ensuring the integrity of *Panax notoginseng* and other herbal products in a dynamic global market.

This study underscores the transformative potential of geographical origin identification, not only as a scientific pursuit but as a practical tool for safeguarding traditions, consumer well-being, and industry sustainability. It marks a significant milestone in the ongoing journey toward innovation, collaboration, and responsible stewardship of natural resources. While this work concludes one chapter, it opens the door to continued exploration and discovery, reinforcing the resilience and integrity of the herbal industry.

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OVERVIEW OF LOAD FORECASTS IN THE CLOUD ENVIRONMENT

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ABSTRACT

In a cloud computing environment, resource scheduling and load prediction are closely related concepts that are closely related to each other. The cloud environment is a virtualized, elastic computing platform that provides various computing resources to users through the network. The cloud environment can provide high scalability and flexibility to meet user demand for computing resources. Load prediction is based on historical data and models to predict and estimate the load in the cloud environment. Load usually refers to the user's demand for computing resources, such as CPU utilization, memory usage, network traffic, etc. The purpose of load prediction is to understand the future load situation in advance in order to plan and schedule resources in the cloud environment reasonably. Resource scheduling is the process of reasonably allocating and managing computing resources in a cloud environment. It is based on the results of load prediction, according to user needs and performance goals, dynamically allocating resources such as computing instances and storage to different tasks and users. The goal of resource scheduling is to optimize resource utilization, improve system performance, ensure service quality and meet user needs. Therefore, the cloud environment, resource scheduling and load prediction are interdependent. Load prediction provides information about future load conditions and provides a basis for resource scheduling decisions. Resource scheduling dynamically adjusts resource allocation based on load prediction results to meet the needs of different tasks and users. Through the coordinated work of load prediction and resource scheduling, resource utilization, performance and user experience in the cloud environment can be optimized. It should be noted that load prediction and resource scheduling are dynamic processes. Due to the uncertainty and variability of the load, prediction and scheduling need to be continuously monitored and adjusted to adapt to real-time demand and environmental changes. Therefore, load prediction and resource scheduling are important research and technical fields in the cloud computing environment, which are essential for improving the efficiency and performance of cloud services.

Keywords:

Cloud environment, decision basis, resource scheduling, resource allocation, load prediction

INTRODUCTION

Resource scheduling refers to the reasonable allocation and management of resources in the cloud environment based on the current load situation and load forecasting results, to meet the needs of applications and optimize system performance (Nayak & Shetty, 2023). The goal of resource scheduling is to achieve efficient use of resources under limited resources, ensuring system availability, performance, and user experience.

Load forecasting refers to the process of predicting and estimating the load situation for a future period of time in a computing system (Mamun et al., 2020). Load refers to the workload or request volume borne by the system, which can be computing tasks, network traffic, user requests, etc. The purpose of load forecasting is to effectively plan resources, optimize system performance, improve user experience, and meet the reliability and availability requirements of the system (Xu et al., 2022).

Load forecasting provides an important reference for resource scheduling (Gao et al., 2020; Mapetu et al., 2021). By accurately predicting the load situation, resources can be allocated and adjusted in advance before load fluctuations occur, avoiding problems of resource shortage or waste. At the same time, load forecasting can also help resource scheduling algorithms better understand load patterns and trends, thereby formulating more reasonable scheduling strategies (J. Kumar & Singh, 2020). It can be said that to a certain extent, load forecasting is the basis for resource scheduling.

PROBLEM STATEMENT

In the cloud environment, resource scheduling and load prediction still face many challenges. The cloud environment usually has the characteristics of large scale, heterogeneity and dynamic changes, so resource scheduling and load prediction face complex environmental and system requirements (Y. Chen et al., 2020; Fu & Zhou, 2020). It is necessary to consider multiple resource types, multiple task requirements, different performance indicators, etc., which increases the complexity of scheduling and prediction (Vashistha & Verma, 2020; Yadav et al., 2021). Load prediction involves estimating future loads, but due to the uncertainty and volatility of the load, accurately predicting future loads is still challenging (Hung et al., 2021; J. Kumar & Singh, 2021). The suddenness, instability and unpredictability of the load will affect the accuracy of load prediction. Load prediction and resource scheduling rely on historical data and real-time monitoring data. However, data quality issues such as incomplete data, data noise, data delay, etc., may affect the accuracy of prediction and the effectiveness of scheduling decisions. Load prediction and resource scheduling involve selecting appropriate algorithms and models and adjusting their parameters to adapt to specific environments and needs (Hou et al., 2021; Shen & Hong, 2020). However, algorithm selection and parameter adjustment may face difficulties. It is necessary to comprehensively consider the performance and adaptability of different algorithms and adjust them according to actual conditions (Karmakar et al., 2020; Lin et al., 2020). The cloud environment usually requires real-time response and adjustment of resource allocation, so load prediction and resource scheduling need to be real-time. However, real-time requirements may increase the complexity of prediction and scheduling, while requiring higher computing and processing capabilities (Nanjappan & Albert, 2022). Resource scheduling needs to balance system performance and cost-effectiveness. For cloud service providers, it is necessary to maximize resource utilization and user experience while controlling costs and the efficiency of resource allocation.

Therefore, this article reviews resource scheduling and load prediction in the cloud environment, finds research gaps and existing problems, and provides a theoretical basis for the feasibility of subsequent research.

LITERATURE REVIEW – Resource Scheduling

Resource scheduling is one of the research hotspots in the field of computer science and distributed systems. With the rapid development of technologies such as cloud computing, big data, and artificial intelligence, resource scheduling is facing increasingly complex and challenging problems (Wadhwa & Aron, 2022). These include the following aspects:

Load imbalance: The goal of resource scheduling is to achieve load balancing, that is, to evenly distribute the load to various resources (Subhash & Udayakumar, 2021; Wadhwa & Aron, 2022). However, due to the dynamic and uncertain nature of the load, resource scheduling may lead to load imbalance problems, where some resources are overloaded while others are underloaded. This can lead to performance degradation, resource waste, and system instability.

Inaccurate prediction: Resource scheduling usually relies on load prediction to predict future load trends and changes (Potu et al., 2021; Yuan et al., 2021). However, load prediction is a complex problem affected by multiple factors such as load fluctuations, seasonal changes, and abnormal events. Inaccurate predictions can lead to unreasonable resource allocation, inability to meet load demand or resource waste.

Data center scale: As the scale of data centers continues to expand, resource scheduling faces greater challenges. Large-scale data centers involve a large number of resources and tasks. Scheduling algorithms and mechanisms need to be able to handle large-scale data and complex scheduling decisions (Geetha & Robin, 2021; Wu et al., 2021). In addition, cross-data center resource scheduling and collaboration are also important issues.

Dynamism and real-time: Resource scheduling needs to monitor the status of loads and resources in real-time and make corresponding scheduling decisions (Geetha & Robin, 2021; Tianqing et al., 2022). However, the dynamic nature of loads and resources makes the scheduling process complex and challenging. Scheduling algorithms need to have real-time response capabilities to adapt to load changes and quickly adjust resource allocation.

Multi-dimensional constraints: Resource scheduling usually involves multiple constraints such as resource capacity, network bandwidth, service quality requirements, etc. Considering multiple constraints at the same time may make the scheduling problem complex and NP-hard (Huang et al., 2022; Singhal & Singhal, 2021). Therefore, designing efficient multi-dimensional scheduling algorithms and strategies is a challenging problem.

High energy consumption and green computing: With the increasing prominence of energy issues, resource scheduling needs to consider energy efficiency and green computing. Unreasonable allocation of resources by resource scheduling may lead to energy waste and high energy consumption (Fan et al., 2021; Strumberger et al., 2019). Therefore, it is necessary to design energy-saving scheduling algorithms and strategies to reduce system energy consumption. At present, many resource scheduling algorithms have been proposed and studied to meet the resource scheduling needs in different scenarios.

Load-balancing-based scheduling algorithms: Load balancing is one of the core goals of resource scheduling (Y. L. Chen et al., 2021; Zheng et al., 2011). Researchers have proposed various load balancing algorithms such as shortest job execution time-based, least connections-based, weighted round-robin-based etc. These algorithms achieve load balancing by reasonably allocating tasks or requests to different resources.

Prediction-based scheduling algorithms: Prediction-based scheduling algorithms use load prediction technology to predict future load conditions and make resource scheduling decisions based on prediction results (Jain et al., 2022). Common prediction algorithms include time series analysis (such as ARIMA models), machine learning (such as regression models, neural networks), and deep learning (such as recurrent neural networks). These algorithms achieve reasonable resource allocation and load balancing by predicting future loads.

Priority-based scheduling algorithms: Priority-based scheduling algorithms prioritize tasks based on their priority or importance and schedule them accordingly (Khodar et al., 2019). These algorithms prioritize high-priority tasks based on factors such as urgency, importance, deadline etc., allocating resources first in order to meet task requirements and system performance requirements.

Heuristic-based scheduling algorithms: Heuristic-based scheduling algorithms use heuristic strategies based on experience and rules for resource scheduling (Javadpour et al., 2022). These algorithms are usually based on some heuristic criteria such as Minimum Slack First (MSF) algorithm or Maximum Slack First (MaxSF) algorithm etc. Heuristic-based scheduling algorithms usually have low computational complexity and fast scheduling speed.

Genetic algorithm-based scheduling algorithms: Genetic algorithm is an optimization algorithm based on evolutionary ideas applied to resource scheduling problems (J. Kumar & Singh, 2020). These algorithms optimize resource scheduling solutions by simulating biological evolution processes. Genetic algorithm has global search capability which can find better solutions for schedule optimization.

Machine learning-based scheduling algorithms: In recent years machine learning technology has been widely used in resource scheduling (Fu & Zhou, 2020). Researchers use machine learning algorithms such as decision trees, support vector machines or random forests etc., learning from historical data about how best to schedule resources.

Table 1: SWOT Analysis of existing Resource Scheduling Algorithm

| | Algorithm | Strengths | Weaknesses | Opportunities | Threats |
|---|---|--|---|--|--|
| 1 | Scheduling Algorithm Based on Load Balancing (Lavanya et al., 2020) | To achieve a balanced distribution of tasks or requests to various resources, improve resource utilization, reduce the load pressure on individual resources, improve system performance, and have a certain degree of elastic adaptability. | This method may introduce certain scheduling overhead, adaptive limitations, and may lack optimization for other constraints, such as energy efficiency and network bandwidth. | With the development of technologies such as machine learning and deep learning, there is an opportunity to apply these technologies to load balancing-based scheduling algorithms to improve load prediction accuracy and scheduling effectiveness. Optimization is performed on the basis of considering multiple constraints. | Some load balancing algorithms may face challenges in complexity and scalability when dealing with large-scale systems or complex scenarios. |
| 2 | Scheduling Algorithm Based on Prediction (Li et al., 2020) | It is possible to accurately predict future load trends based on historical data and predictive models, improving the effectiveness of resource scheduling and planning in advance. | Due to the uncertainty and complexity of load changes, there may be prediction errors, resulting in inaccurate resource scheduling. It is not possible to respond to sudden load changes in real time. | The prediction model can be improved to increase the accuracy and timeliness of predictions. Combined with other constraints, multi-dimensional resource scheduling optimization can be performed. | The prediction model needs to be updated in a timely manner to adapt to changing load patterns and environments, but the cost and frequency of model updates may have a negative impact on system performance. |
| 3 | Priority-Based Scheduling Algorithm (Wang et al., 2020) | Resources can be allocated reasonably according to the priority or importance of tasks to ensure that high-priority tasks are met in a timely manner, providing good service quality and meeting the deadline and performance requirements of tasks. | The priorities of different tasks may conflict, requiring a balance of priorities between different tasks, which may result in a decrease in the performance of some tasks, may not be able to flexibly adapt to dynamic loads and changing environments, and limit the | By combining machine learning and adaptive algorithms, the priority of tasks can be intelligently adjusted to adapt to dynamic loads and environmental changes. | This may lead to the problem of unfair resource allocation, where low-priority tasks may be ignored or not met for a long time. |

| | | | | | |
|---|---|--|---|---|--|
| | | | applicability of the algorithm. | | |
| 4 | Heuristic Scheduling Algorithm (Zhang et al., 2021) | With lower computational complexity and faster scheduling speed, it can quickly respond to load changes. Based on experience and rules, it usually has good interpretability, easy to understand and adjust. | Usually based on fixed rules and strategies, lacking self-learning and adaptive capabilities, it is difficult to adapt to complex load patterns and environmental changes. It may fall into a local optimum and cannot globally optimize resource scheduling problems. | Combining with reinforcement learning algorithms, the heuristic algorithm has the ability to learn and optimize, improving the quality and adaptability of scheduling decisions. Combining heuristic algorithms with other scheduling algorithms, fully utilizing their respective advantages, and improving scheduling effects and performance. | Performance and effectiveness highly depend on the selection of appropriate heuristic rules and parameters, and improper selection may lead to a decline in performance. |
| 5 | Scheduling Algorithm Based on Genetic Algorithm (Saif et al., 2021) | It has global search capabilities and can find better scheduling solutions. Through crossover and mutation operations, it can maintain the diversity of the population and avoid falling into local optima. | It usually takes a long time to evolve and optimize, and is not suitable for real-time scheduling scenarios. The performance of the genetic algorithm highly depends on the selection of appropriate parameter settings, and improper parameter selection may lead to a decline in performance. | By improving the crossover, mutation, and selection operators of the genetic algorithm, as well as optimizing the scheduling strategy, the performance of the genetic algorithm in resource scheduling can be improved. Combining the genetic algorithm with parallel computing and distributed architecture can improve the efficiency and scalability of the algorithm. | The performance and results of the genetic algorithm largely depend on the selection of appropriate genetic algorithm parameters, and improper selection may lead to a decline in performance. |
| 6 | Scheduling Algorithm Based on Machine Learning | Able to learn from historical data, extract patterns and rules, and optimize scheduling decisions. Machine | The demand for a large amount of high-quality training data is high. If the data quality is poor or | By using transfer learning techniques, existing models and knowledge can be utilized in | Machine learning algorithms have a high dependence on high-quality training data. If the data quality is |

| | | | | | |
|--|-----------------------------|---|---|--|--|
| | (Rani & Geethakumari, 2021) | learning algorithms have a certain adaptability and can update and adjust models based on new data and environmental changes. | insufficient, it may affect the performance of the algorithm. Some machine learning algorithms may lack interpretability, making it difficult to explain and understand the decision-making process and results of the algorithm. | different environments and domains to accelerate the training and optimization process of scheduling algorithms. | poor or insufficient, it may affect the performance and accuracy of the algorithm. |
|--|-----------------------------|---|---|--|--|

The review presented in Table 1 has identified a number of weaknesses and issues with current and existing algorithms. Major issues are listed as:

- i. Lack of optimization constraints in energy efficiency and network bandwidth.
- ii. Uncertainty and complexity of load changes,
- iii. Prediction errors,
- iv. Inaccurate resource scheduling.
- v. Inability to respond to sudden load changes in real time.
- vi. Conflict of priorities and balance between different tasks may conflict,
- vii. Decreased adaption flexibility to dynamic loads and changing environments,
- viii. Based on fixed rules and strategies,
- ix. Lack of self-learning and adaptive capabilities,
- x. Risk of falling into a local optimum and might not globally optimize resource scheduling problems.
- xi. Long time to evolve and optimize,
- xii. Not suitable for real-time scheduling scenarios.
- xiii. High dependence on the selection of appropriate parameter settings,
- xiv. Lack of interpretability, making it difficult to explain and understand the decision-making process and results.

LITERATURE REVIEW – Load Prediction

Load forecasting refers to the process of predicting the future load situation of a system based on historical data and models. In cloud computing environments, load forecasting is an important component of resource scheduling. The accuracy of load forecasting directly affects the effectiveness of resource scheduling and system performance (Y. Chen et al., 2020) . The research on load forecasting mainly focuses on the following aspects:

- i. Prediction methods: There are various methods for load prediction, including time series analysis, machine learning methods, statistical methods, etc. (Yadav et al., 2021; Zhang et al., 2021). Time series analysis methods are commonly used for load forecasting, which can capture the trend and seasonality of load changes over time. Machine learning methods such as neural networks, support vector machines, etc. are also widely used in load prediction. These methods can handle complex load patterns and have high prediction accuracy.

- ii. Data source: Load forecasting relies on high-quality data. The data sources usually include historical load data, real-time monitoring data, etc. (M. Kumar & Sharma, 2020; Niri et al., 2020). However, data quality issues such as incomplete data, noise, and latency may affect the accuracy of load forecasting. Therefore, when conducting load prediction, data pre-processing is necessary, such as data cleaning, feature selection, etc.
- iii. Prediction accuracy: The accuracy of load prediction is an important indicator to measure its effectiveness. High precision load forecasting can provide accurate information for resource scheduling, thereby optimizing resource allocation and improving system performance (Rani & Geethakumari, 2021). However, due to the complexity and unpredictability of the load, the accuracy of load prediction still faces challenges. In order to improve prediction accuracy, researchers have proposed various improvement methods, such as combination prediction, ensemble learning, etc.
- iv. Time range of prediction: Load prediction can be short-term prediction, medium-term prediction, or long-term prediction. The application of predictions in resource scheduling varies across different time ranges (Cao et al., 2022; Zhang et al., 2021). Short term forecasting is typically used for real-time resource scheduling, while long-term forecasting is used for resource planning and management. Choosing an appropriate prediction time range can improve the efficiency and accuracy of resource scheduling.
- v. Load pattern recognition: An important task in load prediction is to identify load patterns. Load mode refers to the pattern and characteristics of load changes over time. By identifying load patterns, the dynamic characteristics of loads can be better understood, thereby improving prediction accuracy (Chicco, 2021; Gawlikowski Student Member et al., 2021) . The methods of load pattern recognition include clustering analysis, pattern matching, etc.

METHODOLOGY

This article adopts the literature analysis method to summarize the research status, existing problems, and future research directions of resource scheduling and load forecasting in cloud environments through the study and analysis of relevant literature. Firstly, by searching relevant academic papers, conference papers, technical reports, and other literature, a large amount of information related to resource scheduling and load forecasting was obtained. Then, the content analysis method is used to classify and organize this literature, identifying key issues and challenges in resource scheduling and load forecasting. Finally, based on the characteristics of cloud computing environments, future research directions and possible solutions are proposed.

RESULTS AND DISCUSSION

Through the analysis of literature, this article summarizes several key issues and challenges in resource scheduling and load forecasting in cloud environments. Firstly, the accuracy of load forecasting directly affects the effectiveness of resource scheduling. In order to improve the accuracy of load forecasting, it is necessary to adopt more advanced forecasting models and combine multiple forecasting methods. Secondly, resource scheduling needs to consider multidimensional constraints such as resource capacity, network bandwidth, and service quality requirements. The complexity of these constraints increases the difficulty of resource scheduling. In addition, with the continuous expansion of data center scale, resource scheduling is facing greater challenges. Therefore, future research should focus on developing resource scheduling algorithms and mechanisms that can handle large-scale data and complex constraints.

CONCLUSION

This article provides an overview of resource scheduling and load forecasting in cloud environments, identifies existing research problems and challenges, and proposes future research directions. Firstly, the accuracy of load forecasting is a key factor affecting the effectiveness of resource scheduling. Therefore, future research should focus on developing more accurate predictive models and methods. Secondly, resource scheduling needs to consider multidimensional constraints such as resource capacity, network bandwidth, and service quality requirements. Therefore, researchers need to develop scheduling algorithms that can handle these complex constraints. Finally, with the continuous expansion of data center scale, the challenges faced by resource scheduling are also increasing. Future research should focus on developing resource scheduling mechanisms that can handle large-scale data and complex environments. Overall, by discussing resource scheduling and load forecasting and their related algorithms, the advantages and limitations of different algorithms in practical applications are summarized. The research and development of resource scheduling and load forecasting is crucial for improving the efficiency and reliability of cloud computing systems and is a field that needs to be continuously developed.

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A LITERATURE REVIEW OF THE IMPACT OF SOCIAL MEDIA ON ACADEMIC PERFORMANCE USING MEDIA RICHNESS THEORY

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ABSTRACT

This paper explores the impact of social media on academic performance by using Media Richness Theory (MRT). First, the paper presents the growing importance of social media in students' lives and discusses scholars' perspectives on its potential impact on academic performance. Past research has found a complex relationship between social media usage, academic activities, and academic performance. Second, the paper introduces Media Richness Theory (MRT), which has been used to assess the success of different learning channels and, in an educational context, MRT has been applied to assess the impact of social media on academic performance. In terms of the specific impact of social media on academic performance, this paper summarizes the different perspectives of selected studies. On the one hand, some studies suggest that excessive use of social media may have negative effects on academic performance, including distraction, low motivation, and reduced study time. On the other hand, some studies suggest that responsible and prudent use of social media may improve academic performance and promote resource sharing and collaborative learning. Taken together, the impact of social media varies depending on several factors, including usage habits, personal characteristics, and the type of platform used. In order to maximize the positive impact of social media, students should use it in a planned and controlled manner to ensure that they get the most out of their academic experience.

Keywords:

Social Media, Academic Performance, Media Richness Theory, Literature Review

INTRODUCTION

The popularity of the Internet, the impact of big data, and the flourishing of social networking platforms have dramatically changed the dynamics of human interaction (Yeung, 2018). The emergence of devices such as smartphones and smartwatches has further blurred the boundaries between individuals and expanded the scope of socialization (Lu, 2020). As a result, students increasingly rely on social media to accomplish daily tasks ranging from attending lectures to completing assignments (Mohammed et al., 2021). The growing importance of social media in the academic environment raises important questions about its impact on academic performance.

Scholars have recognized the potential of social media as a tool to enhance student well-being (Mitev et al., 2021). However, the relationship between social media use and academic performance is a subtle and multilayered theme. Some studies have shown a negative correlation, particularly in terms of time spent on social media use (Boahene et al., 2019; Celestine & Nonyelum, 2018; Hasnain et al., 2015), while others have suggested that a positive attitude towards social media can potentially improve academic performance by providing students with greater access to information (Oguguo et al., 2020).

This complex interaction between social media and academic performance prompts us to explore theoretical frameworks that can provide insights into the underlying mechanisms. One such framework that holds promise for understanding this relationship is Media Richness Theory (MRT) (Peñalba, 2020), which posits that the effectiveness of communication is influenced by the richness of the medium used. Since social media platforms vary in providing communication richness, applying MRT to the study of the impact of social media on academic performance can provide a nuanced understanding of the phenomenon. This study aims to reveal the multiple ways in which social media may influence students'

academic efforts in an educational context. Therefore, the purpose of this paper is to explore the relationship between social media and academic performance using media richness theory as a guiding framework, and by reviewing and analyzing the previous literature, this study aims to reveal the multiple ways in which social media may influence students' academic efforts in an educational context.

EMERGENCE OF SOCIAL MEDIA

The history of social media can be traced back to the emergence of early online communities and bulletin board systems, which were then online channels that supported simple content posting and discussion among Internet users (Aichner et al., 2021). Internet users can utilize a variety of websites, apps, and online platforms to stay connected with others, get news, and access information from different sources (Halkiopoulos & Giotopoulos, 2022). In addition, these channels facilitate the sharing of personal thoughts and experiences with the global community, a phenomenon commonly known as social media usage.

For a significant portion of the public, social media platforms have replaced traditional media as their primary source of news and information. Al-Rawi (2019) noted that news articles and information can spread quickly on social media due to the "viral" approach to sharing material. This impact can often directly and quickly influence public discussion of relevant news and events, and even generate widespread public opinion.

Users can actively generate and share social media profiles, such as text, photos and videos, on social media platforms. At the same time, social media promotes user engagement, enabling people to participate in interactive communication, teamwork and content co-creation (Sashi, 2021). With the help of these features, users can actively contribute to the content of online platforms, form their online identities and build social relationships. Consumer behavior is also impacted by social media (Shao & Ibrahim, 2024).

However, the growth of "social media" has also raised significant concerns about personal security and privacy. Jain et al. (2021) illustrated that users often divulge personal information on social media sites, raising questions about the security and privacy of this information. In addition, studies have shown that excessive use of social media may have harmful psychological effects, such as increased anxiety, despair and social comparison (Keles et al., 2020; Nesi & Prinstein, 2015; Orben et al., 2020). As a result, more and more platforms are beginning to emphasize that they have robust and effective usage guidelines and privacy policies.

SOCIAL MEDIA IN HIGHER EDUCATION INSTITUTIONS

Owing to the global health emergency caused by the COVID-19 pandemic in early 2020, the majority of educational institutions worldwide were forced to modify their face-to-face teaching methods and replace them with new online learning strategies (Zakariah, 2023). In this context, technology advancements have encouraged the widespread use of online learning environments, providing access to a wider variety of flexible means for acquiring knowledge. This shift has not only influenced education but has also facilitated the sharing of resources and the advancement of educational justice (Dong & Mustapha, 2021), alongside the growing impact of social media on various aspects of life. Institutions of higher education are increasingly recognizing the potential of social media platforms to enhance teaching, learning and student engagement (Manu et al., 2021). These platforms offer unique opportunities for collaboration, interaction and connection between students and educators within higher education institutions.

Masrom et al. (2021) stated that the ubiquity of the Internet has made social networking a global phenomenon, especially ubiquitous among college students. A study by Alnjadat et al. (2019) showed that social networking is one of the most popular pastimes among university students, and as a result, it

has a profound impact on their daily lives. Bhandarkar et al. (2021) demonstrated a correlation between social media usage and the academic performance of undergraduate medical students. Additionally, a study by Zachos et al. (2018) emphasized the potential of social media in facilitating communication and collaboration as well as expanding the scope of learning. Through these platforms, students can interact with course materials, access additional learning materials, and engage in debates that encourage originality, innovation, and a focus on research. Teachers can utilize the potential of social media to design dynamic and interactive learning environments outside of the traditional classroom. Therefore, it is important for higher education institutions to explore and embrace diverse social media platforms to expand the learning environment and cater to students' preferences and learning styles.

The influence of social media in higher education institutions is growing by the day and has far-reaching implications for the future. By embracing social media platforms, educators can create engaging learning environments, foster collaboration, and promote global connections among students. Social media plays an important role in the lives of today's students and has a huge and lasting impact on their academic performance (Appel et al., 2020).

Despite the many advantages of integrating social media into higher education, there are some issues that must be addressed. Gulzar et al. (2022) emphasized the importance of considering the effects of cyberbullying in educational settings and promoting social media usage responsibly. Privacy concerns and potential distractions are also important factors that must be addressed. Institutions of higher education should develop clear guidelines, policies, and support systems to promote responsible and ethical use of social media. Educators should receive appropriate training and resources to effectively incorporate social media platforms into their teaching practices while promoting digital citizenship and cyber safety among students (Giesenbauer & Müller-Christ, 2020).

The relationship between social media usage and academic performance is intricate and has both positive and negative effects (Whelan et al., 2020). Research has shown that social media use affects student academic performance in a variety of ways. Some investigations have shown that active use of social media can improve students' ability to engage in academic activities and access information. For example, a study conducted by Bhandarkar et al. (2021) showed a positive correlation between academic performance and activities such as reading health-related news, completing assignments, and conducting academic research on social media platforms. In essence, social media platforms have a significant impact on the sustainability of students' academic performance. In addition, a survey by Mindajao (2023) found that there is no significant correlation between social media addiction and students' academic performance. Therefore, students' poor performance in science subjects cannot be solely attributed to social media addiction.

A comprehensive literature study by Tang et al. (2021) examined how young Chinese people utilizes social media. Their study aimed to fill the knowledge gaps regarding the themes, theories, factors, and conceptual frameworks of social media use among young Chinese. The study suggested that future research on social media should utilize other theories or models, cover a larger range of topics, and involve more social media platforms. According to Zachos et al. (2018), the usage of social networks in higher education had a favorable impact on students' learning process, academic performance, and teaching effectiveness. Their study examined educators' and students' usage of social networks to provide support, improve communication and teamwork as well as learning management systems. The findings suggest that social networks have multiple uses in higher education. However, academics and higher education institutions have not yet fully utilized the potential of social networks.

Therefore, further extensive research must be conducted to understand the underlying mechanisms by which social media impacts student learning and to identify the best strategies for leveraging its positive effects while mitigating potential drawbacks (Kitsantas et al., 2016). The growing influence of social media in higher education provides a wealth of opportunities for the future of education. By delving into the mechanisms of social media's effects, educators and institutions can better guide students to fully utilize this tool for academic achievement and global connections.

MEDIA RICHNESS THEORY (MRT)

Brief Introduction of MRT

Strategic media usage becomes essential for efficient corporate communication when handling a variety of job tasks and media sources. Media Richness Theory (MRT) was developed in 1984 by Richard L. Daft and Robert H. Lengel to address communication issues in businesses (Ishii et al., 2019).

MRT seeks to identify and assess communication mediums inside companies. It is based on information processing theory (Daft & Lengel, 1986). Information richness is the main emphasis of Daft and Lengel (1986), who measure how much a message may change comprehension in a specific amount of time. According to them, the more cues and information that are required for an appropriate interpretation of a message, the more ambiguous it is (Dennis & Valacich, 1999).

As per MRT, the four fundamental attributes that determine media richness are Immediate Feedback (IF), Multiple Cues (MC), Language Variety (LV), and Personal Focus (PF). Real-time, two-way feedback is a feature of IF that boosts motivation and engagement. MC conveys a lot of information by using contextual cues and nonverbal cues. Different linguistic phrases are included in language variety, which is important for accurate communication. The term "personal focus" describes the capacity of media to offer tailored information and individualized attention while boosting productivity.

According to Lee (2022), "lean" media are incapable of supporting communication akin to in-person interactions, but "rich" media can. The capacity of a medium to offer quick feedback, a diversity of cues, a wide range of languages, and individualized attention are the main factors used to assess its richness. Communication in person is seen to be the most fruitful form of communication, followed by phone, written addressed communication, and unaddressed communication.

MRT's four defining features can be dissected as follows:

(a) Immediate Feedback (IF): Two-way feedback that is given in real-time improves motivation, engagement, and content production. Strong user-producer rapport, stickiness, and retention are all facilitated by IF.

(c) Multiple Cues (MC): A multitude of information is sent through nonverbal cues and contextual details, which influence how messages are interpreted. In face-to-face communication, MC facilitates understanding of intentions and feelings.

(b) Language Variety (LV): A wide range of linguistic phrases enable clear and concise messages to be communicated in a variety of cultural and linguistic contexts.

(d) Personal Focus (PF): Capacity to tailor communication and attention to each person's requirements. High-personal attention media improve efficiency and effectiveness.

MRT prioritizes meeting user needs and providing individualized attention. In the age of digital media, creating media forms that address users' issues and offer personalized and targeted information requires a thorough understanding of each user's demands. To sum up, rich media content increases user satisfaction and productivity (Lee, 2022).

The graphical depiction of MRT in Figure 1 demonstrates the diversity and power of media (Za & Braccini, 2012). It implies that leaner media is appropriate for simple activities while richer media is recommended for complicated, introspective, and creative jobs (Drew, 2023). Six papers that examine the nature, evolution, and implementation of MRT shed light on the subject. To direct future research on social media and new media, the theory will continue to be fundamental.

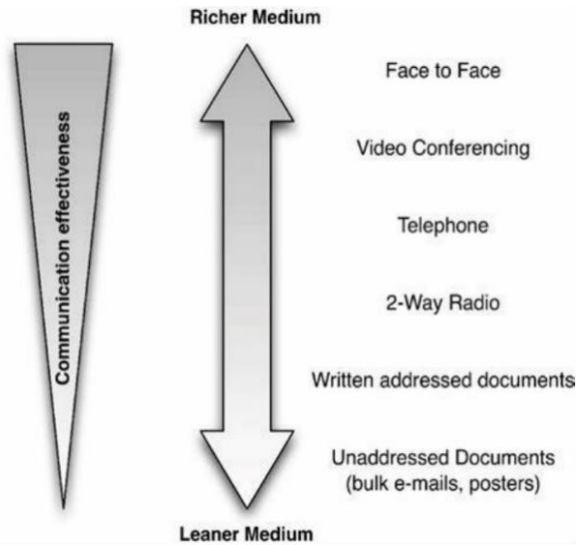


Figure 1: Media Richness Theory

MRT in Educational Context

The notion of media richness stimulates viewers' interest in the selected medium and evokes an emotional response, which acts as a catalyst for people to engage in exploratory activities that are full of zeal and curiosity (Novak et al., 2000). Many academics have been interested in exploring the many uses and implications of this conceptual framework, which has been the focus of much research in the field.

Blau et al. (2017) showed that MRT has been continuously refined after many validations and has recently been extended to emerging media, such as online conferences, video chats, and e-learning methods. In addition, the theory has been widely used to assess the relative success of different learning channels in educational settings (Ishii et al., 2019). This suggests that advanced technology is recognized as a crucial tool for teacher/student and teacher/student parent communication in both traditional and online courses.

Specifically, in a comparative experiment conducted by Lan et al. (2011) researchers placed elementary school students in a traditional classroom and a new computerized media classroom for writing exercises to explore the effects of different instructional models on student achievement. The results of the study indicated that students who were taught using the Internet in the computerized classroom made more significant progress in writing. However, Cole's (2016) study pointed out that in higher education, dropout rates are higher in online courses because students prefer face-to-face teaching methods, which supports the idea of MRT.

According to (Ishii et al., 2019), teachers in grades K-12 are in constant contact with their students' parents. Regarding sensitive topics (e.g., children's health and character), parents prefer richer media that provide quick responses and organic interactions, such as face-to-face communication. However, email became the primary way parents communicated with teachers about their child's status, especially when it came to academic performance, as many parents found the asynchronous nature of email helpful in keeping in touch with busy teachers (Thompson & Mazer, 2012).

Another study (Conradie et al., 2014) noted that when students use a learning management system, "immediate feedback" and "multiple cues" (two factors of MRT that have been mentioned and explained previously) are significant correlations. The theory applies not only to emerging media, but also to other communication media content such as online conferences, video calls, and online courses, highlighting its broad applicability in all types of media environments.

IMPACT OF SOCIAL MEDIA ON ACADEMIC PERFORMANCE USING MEDIA RICHNESS THEORY

Face-to-face contact was regarded as the richest form of communication in MRT's media classification, while print and email were considered the worst. Particularly when it comes to face-to-face communication, team effectiveness, and task completion rates are enhanced (Yuan & Wu, 2020). Emerging social media platforms, however, provide simplicity and more advantages for information management. Social media is becoming the primary means of communication for millennials, steadily displacing more conventional channels like email. Because of this, student virtual teams have more alternatives when it comes to media, such as social networking and file sharing, which opens up more opportunities for teamwork (Kim et al., 2020).

In an investigation examining the effects of students' use of various media when working in a virtual team setting, Aritz et al. (2018) polled 304 undergraduate students in 75 teams. The study found that, particularly on more sophisticated social media platforms, better-coordinated teams were able to identify the importance of social networks and richer communication channels earlier than less-coordinated teams. Media Richness Theory (MRT), according to Aritz et al. (2018), indicates that work performance may be enhanced by the employment of more advanced communication technologies.

Azizi et al. (2019) and Sampasa-Kanyinga et al. (2019) found that excessive usage of social media negatively impacts students' academic performance. Overuse of social media can cause distraction, low motivation, and less time spent studying. For instance, students' academic performance may suffer if they spend too much time on social media and participating in virtual socializing, as this might cut into their study time and energy (Appel et al., 2020).

Nonetheless, not every study finds a link between students' usage of social media and poor academic achievement. According to some research (Bernacki et al., 2020; Luqman et al., 2021), students may enhance their academic performance by using social media responsibly and prudently, which can offer them resources and learning possibilities. As a consequence, some educators and educational institutions use social media to share teaching resources with students to foster group projects, encourage creativity, and encourage critical thinking.

CONCLUSION

In general, several factors influence students' academic performance regarding social media use. Because social media encourages knowledge sharing, collaborative learning, and creative thinking, students' academic performance may benefit from its deliberate and moderate use. Students may readily access educational materials, take part in conversations, and communicate with classmates and professors immediately via social media platforms, all of which can enhance the learning process.

It is crucial to remember that this link is dynamic and that a variety of factors, including use habits, individual characteristics, the kinds of social media platforms used, and environmental and personal circumstances, may be significant influences. While some students could be better able to control their social media use so that it doesn't interfere with their education, others might be more prone to social media interruptions, which might result in problems like decreased study time and distraction.

In this situation, using social media in a planned and controlled manner is essential. By setting explicit learning objectives, scheduling social media time, and selecting platforms that are appropriate for learning, students may more effectively weigh the benefits and drawbacks of social media. In general, social media may be beneficial for students' academic achievement; but, to guarantee this, it must be used sensibly and with caution.

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THE RELATIONSHIP BETWEEN MARITAL SATISFACTION, FAMILY SUPPORT AND PSYCHOLOGICAL DISTRESS TOWARDS WELL-BEING AMONG MARRIED ADULTS IN PETALING JAYA, SELANGOR

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ABSTRACT

This study aimed to determine the relationship between marital satisfaction, family support, and psychological distress towards well-being among married adults in Petaling Jaya, Selangor. Additionally, the study aimed to identify predictors of well-being model among married adults in the same area. The research design used in this study was quantitative and data were collected through a survey. The sample consisted of 384 married participants aged between 25-54 years old who were recruited through convenience sampling. The data collected were analyzed using SPSS for Pearson Correlation and Regression. The study found that all three variables, namely marital satisfaction, family support, and psychological distress, were significant correlates with the well-being among married adults in Petaling Jaya. However, based on the regression analysis, the well-being model is only influenced by marital satisfaction and psychological distress. This study contributes to the understanding of the factors that affect well-being among married adults in Petaling Jaya, Selangor. The findings have implications for policymakers and mental health practitioners in developing interventions that target the specific needs of them married adults in terms of their well-being. Future studies could examine the impact of additional factors such as culture, religion, and social support on the well-being among married adults.

Keywords:

Marital Satisfaction, Family Support, Psychological Distress, Well-Being, Adults

INTRODUCTION

Marriage is the dominant social relationship in adulthood and is closely related to an individual's subjective well-being, physical as well as the psychosocial health (Carr, Freedman, Cornman & Schwarz, 2014). Previous research has shown that people who marry live longer, happier lives and are less likely to suffer from mental illness (Waite & Gallagher, 2001; Diener & Chan, 2011). Researchers also have suggested that marriage protects and promotes subjective well-being through multiple mechanisms such as the sharing of economic resources, social and emotional support and social control (Newman, Tay & Diener, 2014; Perelli-Harris, et al., 2019).

According to a study conducted by the State Population and Family Development Institute (LPPKN) in 2010, the values and dynamics of family life are changing with the times (Hamjah, et al., 2020). One notable change is the trend towards smaller family sizes. Another change is the significant increase in the amount of time women spend working outside the home, which poses challenges in balancing work and domestic responsibilities. Furthermore, individuals who pursue careers may be hesitant to have children due to concerns about the impact on their professional progress, while those who do have children may struggle to find suitable caregivers while they are at work (Cuong & Linh, 2016).

The pressures of life today also affect the need for education and work for every individual including women (Delina & Raya, 2013). Moreover, Kromydas (2020) stated that education greatly affects job opportunities and wages, with more women joining both education and workforce. In some situation, the changes of workforce among the women could also lead to the conflict in term of work division within the household with the traditional gender roles are challenged. These changes required

adaptation and tolerance among family members, eventually contributing to their overall well-being. Well-being among adults can be influenced by a variety of factors, including personal, social, and economic factors. Personal factors that can affect well-being include physical health, mental health, and individual behaviour and choices (Velten, et al., 2018). Social factors that can affect well-being include social support, social connections, and community involvement (Goaswami, et al., 2010). Economic factors that can affect well-being include income, employment, and access to resources (Hajkowicz, Heyenga & Moffat, 2011).

There has been a significant amount of research on the well-being of adults (Rogers et al., 2012; Wright, Williams & Weldhuijzen van Zanten, 2021). Some key findings from the previous research reported that physical health is a major determinant of well-being. Mental health is also a major determinant of well-being in which good mental health is associated with higher levels of well-being, while poor mental health can have a negative impact on well-being. Other than physical health, factor related to well-being of the adult is the social connection. Having strong social connections, including family, friends, and community involvement, is associated with higher levels of well-being. Finally, from the perspective of financial, higher levels of income and employment are associated with higher levels of well-being, while lower levels of income and employment can have a negative impact on well-being.

One of the explanations in the context of factors towards the well-being among the married adults is the interdependence theory by Harold Kelley and John Thibaut. The theory applied in this study explains how individuals in close relationships, such as marriage, influence each other's thoughts, emotions and behaviors (Rumble, 2022). In the context of married adults, this theory is particularly relevant to understanding their well-being. In this theory, individuals evaluate their relationship where it is shaped by past experiences and societal expectations. If the outcomes of a marriage exceed one's expectation, satisfaction is likely to be high. In short, interdependence theory emphasizes that the well-being of married adults depends on the balance of rewards and costs in the relationship, their standards and expectations and also the couples' ability to work together as a team. Strong, supportive interdependence fosters satisfaction and personal growth, while imbalances can lead to conflict and dissatisfaction.

There are a number of challenges to achieving and maintaining well-being among adults, especially for the married individual. Failure to cope with challenges in marriage life could lead to the well-being distortion. Approximately one in five adults in the United States (20.9%) experiences a mental illness in any given year (Bitsko, et al., 2022). Approximately 28% of adults in the United States report feeling lonely, and 27% report feeling isolated from others (Choi, et al., 2022). While in Malaysia, a study conducted by Hussein, Ismail and Abu Bakar (2021) on 380 adults reported that majority of the sample experienced social loneliness and depression. These statistics highlight some of the common challenges to achieving and maintaining well-being among adults, including mental health issues, chronic health conditions, social isolation, poverty, and unemployment. These challenges can have a negative impact on well-being, and addressing them is important for improving the well-being of adults.

The issue of the extent to which marriage leads to individual well-being has long been debated in the field of psychology. Apart from that, research has also highlighted a good quality of well-being among married adults as an important indicator towards positive emotions. Study by Grundstrom, Kontinen, Berg and Kiviruusu (2021) reported that there is a significant relationship between support from family members and well-being. In that study, it was found that for individual who reported having a good social support from their partner would perceive a stronger self-esteem. In short, marriage served as a platform for social support to gain a better well-being among individual. In result, adults with strong well-being are more likely to be healthy and productive, while being less prone to mental and physical health challenges. When adults have good well-being, they are more likely to contribute to their communities and to the broader economy, which can help to improve overall social and economic well-being.

Finally, addressing well-being among adults is important because it can help to reduce social and economic disparities (Rogers, et al., 2012). Married adults' well-being is significant to maintain the

family function as well as the members in the circle via understanding the factors that lead to the positive outcome of the unit. Therefore, this study focuses in examining the factors of marital satisfaction, family support and psychological distress towards the psychological well-being of married adults. The research objectives of the study are as follows. Table 1 indicates the conceptual framework.

- (i) To determine the relationship between marital satisfaction, family support and psychological distress towards well-being among married adults in Petaling Jaya, Selangor.
- (ii) To determine the predictors towards well-being among married adults in Petaling Jaya, Selangor.

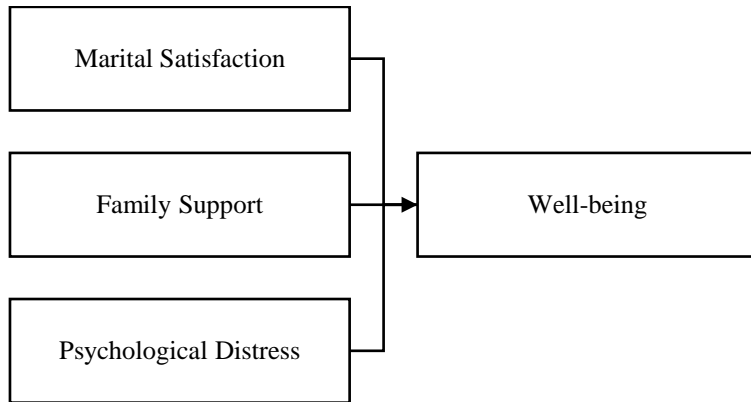


Table 1: Conceptual Framework of Marital Satisfaction, Family Support and Psychological Distress Towards Well-Being among Married Adults

In this study, null hypothesis as below are used to test the objective of the study:

Ho1: There is no significant relationship between marital satisfaction and well-being among married adults.

Ho2: There is no significant relationship between family support and well-being among married adults.

Ho3: There is no significant relationship between psychological distress and well-being among married adults.

Ho4: There are no significant influences of marital satisfaction, family support, and psychological distress towards well-being among married adults.

LITERATURE REVIEW

The literature suggests that there is a complex relationship between marital satisfaction, family support, psychological distress, and well-being among married adults. Studies have consistently found that higher levels of marital satisfaction and family support are associated with better overall well-being, including emotional, social, and psychological well-being. Conversely, psychological distress has been found to have a negative impact on well-being. While there is a general consensus on the importance of marital satisfaction and family support for well-being, it is important to note that the relationship between these

factors is not always straightforward and may vary depending on individual and cultural contexts. For example, cultural expectations around marriage and family relationships may influence the extent to which marital satisfaction and family support impact well-being. Additionally, factors such as economic status, social support networks, and individual coping strategies may also play a role in determining the impact of these factors on well-being.

Moreover, researches have highlighted the marital satisfaction and family support may contribute to better mental health outcomes (Demirci & Odacı, 2020; Prabhakar, Ramanathan, Kalaivani & Selvakumar, (2022). Recent study done by Acibal, Kaya, Fernandez-Batanero and Çotok (2023) has emphasized the role of resilience in mediating the relationship between these factors and well-being. Resilience refers to the ability to adapt to stress and adversity, and research done by Acibal et al., (2023) has shown that individuals with higher levels of support from the spouse are able to cope better with the challenges of married life and maintain positive relationships.

The well-being of an individual depends a lot on the psychological well-being experienced by the individual. Being happy or not is something abstract and subjective (Angner, 2010). Following the World Health Organisation (WHO), human well-being is usually seen from a psychological perspective that includes cognitive and affective aspects (Vazquez, et al., 2009). These cognitive and affective aspects also refer to positive and negative feelings about life so far and focus more on satisfaction in life. Among them are such as marital satisfaction, life satisfaction, satisfaction in a family atmosphere, and less experiencing extreme depression and anxiety.

The concept of well-being is deeply intertwined with human nature and satisfaction in life (Ryff & Singer, 2008). Life satisfaction is an essential predictor and mediator of well-being in individuals, and low life satisfaction is often associated with difficulties in achieving overall well-being, particularly in adolescence (Kashdan & Steger, 2007). Psychological well-being involves living a good life, which includes good feelings and effective functioning (Diener, et al., 2009). Efficient well-being does not require individuals to feel good throughout life, as experiencing painful emotions (such as failure, disappointment, sadness) is a normal part of life.

The ability to manage negative or painful emotions is necessary for long-term well-being, as sometimes negative emotions are so severe and long-lasting that they interfere with an individual's ability to function in life. Psychological well-being also refers to well-being obtained from various aspects such as social, psychological, or freedom needs that affect personal growth (Ng & Diener, 2014). Ryff (1989) sees this element as an attempt to achieve perfection based on the realization of one's true potential and categorizes psychological well-being into six main elements as measurements, namely autonomy, environmental control, self-development, positive relationships with others, life goals and self-acceptance. These elements become a measure of psychological well-being for individuals and help towards family well-being in society.

For this study, psychological and individual well-being are based on family happiness or well-being of a family and these guidelines are applied to make the family as harmonious and peaceful as every individual wants (Benjamin, et al., 2014). Psychological well-being can be influenced by several key factors such as the quality of relationships within the family, the level of internal stress, physical health and good intimacy with friends (Darling, et al., 2007). All of these depend on the extent to which individuals stabilize themselves and maintain that state for internal and external health. This situation also shows that meaning to a life is a sense of fulfilment from all aspects because such a feeling becomes a protector of emotional stability, a guarantee of psychological health and well-being. Meaning in a life is very important to individuals, families, and society.

Marriage is a significant and long-term relationship that involves legal and religious commitments and affects not only the couples but also other individuals in the society. Therefore, it requires special attention and care to ensure maximum marital satisfaction (Schwartz & Scott, 2011). A happy and harmonious marriage is essential for a nuclear family's subsystem and, in turn, society's well-being (Gable, Belsky & Crnic, 1992).

Maintaining marital satisfaction is a challenging aspect of married life that couples must face. Balancing family and work needs is one of the main challenges, and having a good rapport is crucial to achieve marital satisfaction and maintain the marriage built (Renalds, 2011; Barahmand & Nafs, 2013). Marital satisfaction is one of the benchmarks for measuring the happiness and well-being of married adults, according to psychologists and marriage experts (Ates, 2018; Yildiz & Baytemir, 2016).

Studies have found that happy marriages have positive impacts on the psychological development of married individuals, their children, and those directly and indirectly related to them. Married individuals with high marital satisfaction report better health, lower stress, and reduced symptoms of depression while carrying out parental duties. Moreover, parents with high marital satisfaction can produce psychologically prosperous children and improve child well-being. Additionally, how parents handle marital conflict is closely related to their children's ability to manage emotions (Carr et al., 2014).

Marital satisfaction and emotional intelligence are closely related. Studies have found that married individuals report an increase in marital satisfaction when their level of emotional intelligence is high. Emotional intelligence is an essential element in understanding human thoughts, feelings, and behaviors for married individuals. Researchers have defined emotional intelligence as "the ability to perceive and express emotions, assimilate emotions in the mind, understand and deal with emotions, and control the emotions of oneself and others" (Mayer et al., 2000). Study has focused on marital satisfaction and emotional intelligence, with reviewers suggesting that studies focus on specific cultures to understand emotional intelligence and marital satisfaction (Schutte et al., 2001).

Other than that, family is defined as a group of people with ties of marriage, birth, and adoption that aims to create, maintain culture, and enhance the physical, mental, emotional, and social development of each family member (Zaid & Setiawati, 2019). The family is an important entity in energizing and encouraging a person to succeed in their career and personal life. Emotional and moral support from life partners is one of the important aspects driving expatriate success, as it helps married adults in dealing with problems and increasing their self-confidence (Toh & Denisi, 2005; Lewis et al., 2008). Support from family, especially in terms of family encouragement, attitude, behavior, and understanding of a situation, has a positive impact on a person's well-being (Kossek et al., 2001). Family support is also critical for married working adults to overcome stress and maintain good well-being (Scheyvens et al., 2021).

Numerous studies have investigated the relationship between psychological distress and well-being in the workplace. Winefield et al. (2012) found that psychological distress and well-being are positively related, indicating that stress levels can affect an individual's overall well-being. Additionally, a positive work environment and job satisfaction can contribute to an individual's psychological well-being (Leung, Siu & Spector, 2000). In terms of gender differences, Nelson and Burke (2000) suggest that men experience less pressure than women, while Pietilla and Rytkonen (2008) argue that men experience higher levels of stress than women. Regarding education, Sunil and Rooprai (2009) found that education is not a basis for psychological distress differences among the adults.

METHOD

The research design for this study is a quantitative methodology that involves the use of survey to collect data from a large and diverse group of the target population, which is the married adults.

Population and Sample:

The samples in this study are the married couples in Petaling Jaya area. Petaling Jaya City Council (MBPJ) reported that as of July 2022, the total population of Petaling Jaya was over 619,925 people ("Background - Petaling Jaya City Council," n.d.). The target population for this study are married adults in the Petaling Jaya area who are aged between 25 to 54 years old as of 2022. The inclusion criteria of the population also include adults who are currently staying with their spouse with or without children. According to the Central Intelligence Agency (2021), 40.86% of the population of Malaysians falls within the age range of 25 to 54 years old. This means that out of a total population of 619,925 in Petaling Jaya, we can estimate that $619925 * 40.86\% = 253,301$ people are aged between 25 to 54 years old. Assuming that half of these adults are married, we can calculate the number of married adults within this age range as $253,301 * 50\% = 126,650$. Rounded to the nearest whole number, this gives an estimated 120,000 married adults who match the target population criteria in Petaling Jaya. Krejcie and Morgan (1970) have designed a table to determine the sample size for a given population so that it is easy for researchers to determine the sample size of research to be collected given the size of the population. Hence if the given population is large, the required sample size is 384.

Research Instrument:

The data for this study were gathered through the use of a research tool called a survey. A research questionnaire is designed to ask relevant questions to the respondents regarding the research study. The survey questionnaire is designed to collect data on the well-being of married adults residing in Petaling Jaya, by measuring their level of well-being as the dependent variable, and marital satisfaction, family support, and psychological distress as independent variables. The questionnaire consists of four sections; Section A, Section B, Section C and Section D.

Section A is a confirmatory section that asks three simple yes/no questions to confirm the respondents' marital status, current living situation, and place of residence. Section B contains questions related to the dependent variable, which is well-being. The questions are designed to measure the respondent's level of agreement with statements related to their well-being in the past month. The examples for the items from the eight questions used to measure well-being are "I have been in good spirits in the past month" and "I am happy and satisfied with my personal life in the past month". These questions were adopted from previous research by Chuah, Lee, and Tan (2022). The questions are rated on a 5-point Likert scale, with 1 representing Strongly Disagree, 2 representing Disagree, 3 representing Neutral, 4 representing Agree, and 5 representing Strongly Agree.

Section C contains questions related to the three independent variables. The first independent variable is marital satisfaction, which is measured by six questions that ask about the respondent's overall satisfaction with their relationship with their partner. Example of the questions are "My partner meets my needs well", "My relationship is good compared to most" and "There are hardly any problems in my relationship". These questions are rated on a 5-point Likert scale, with 1 representing Strongly Disagree, 2 representing Disagree, 3 representing Neutral, 4 representing Agree, and 5 representing Strongly Agree. The questions used in this section were adapted from Chuah, Lee and Tan (2022).

The second independent variable is family support, which is measured by six questions that ask about the respondent's perception of the emotional and practical support provided by their family. These questions are rated on a 5-point Likert scale, with 1 representing Strongly Disagree, 2 representing Disagree, 3 representing Neutral, 4 representing Agree, and 5 representing Strongly Agree. The questions used in this section were adapted from Rashid et al. (2011).

The third independent variable is psychological distress, which is measured using seven questions. The questions are designed to measure the respondent's level of agreement with statements related to their psychological distress. These questions are rated on a 5-point Likert scale, with 1 representing Strongly Disagree, 2 representing Disagree, 3 representing Neutral, 4 representing Agree, and 5 representing Strongly Agree. These questions were adopted from previous research by Tini (2021). The questions related to marital satisfaction were adapted from previous research by Chuah, Lee, and Tan (2022), while the questions related to family support were adapted from research by Rashid et al. (2011). The questions related to psychological distress were developed for this study. Section D contains questions related to demographic variables, including gender, ethnicity, highest education level, age group, and monthly income level. The respondents were asked to select the appropriate answer from the provided options.

Data Collection:

After the questionnaire has been approved and validated among the researchers and designed into the format of Google Forms. Various social media platforms used to collect data via Whatsapp groups, WeChat and Facebook.

This research applies the convenience sampling method with a targeted criteria which is married adult.. Once the respondents agreed to participate, they will fill up a consent form before proceeding to the items. The survey completed with a total of 384 responses.

Data Analysis:

Pearson's correlation was applied to test the hypotheses one to three. As for fourth hypothesis, regressions analysis was used to determine the predictors of marital satisfaction model among the married adults in this study.

RESULT AND DISCUSSION

The results in Table 2 indicated that there were slightly more male participants (n = 206) than female participants (n = 178). The majority of participants identified as Chinese (n = 171), followed by Malay (n = 127) and Indian (n = 60). There were also 26 participants who identified as belonging to other ethnicities. In terms of education level, the highest proportion of participants reported having SPM or equivalent qualifications (n = 158), followed by undergraduates (n = 123), A-Levels or equivalent (n = 65), and postgraduates (n = 38). The age of the participants ranged from 25 to 54 years old, with the highest frequency in the 35 to 39 years old age group (n = 100). The income level of participants varied, with the highest frequency in the RM5000 to Rm10 000 income range (n = 152). Followed by RM3000-RM5000 (n = 143) and less than RM3,000 (n = 72). The smallest group is the individual with more than RM10,000 per month, with only 17 participants.

Table 2: Demographic Details of the Respondents

| Demographic Attributes | Frequency |
|-------------------------------|------------------|
| Gender | |
| Female | 178 |
| Male | 206 |
| Ethnicity | |
| Chinese | 171 |
| Indian | 60 |
| Malay | 127 |
| Others | 26 |

| | |
|--------------------------------|-----|
| Highest Education Level | |
| SPM or equivalent | 158 |
| A-Levels or equivalent | 65 |
| Undergraduates | 123 |
| Postgraduates | 38 |
| Age Group | |
| 25 to 29 years old | 27 |
| 30 to 34 years old | 55 |
| 35 to 39 years old | 100 |
| 40 to 44 years old | 81 |
| 45 to 49 years old | 45 |
| 50 to 54 years old | 76 |
| Monthly Income Level | |
| Less than RM3,000 | 72 |
| RM3,000 to RM5,000 | 143 |
| RM5,000 to RM10,000 | 152 |
| More than RM10,000 | 17 |
| Gender | |
| Female | 178 |
| Male | 206 |
| Ethnicity | |
| Chinese | 171 |
| Indian | 60 |
| Malay | 127 |
| Others | 26 |
| Highest Education Level | |
| SPM or equivalent | 158 |
| A-Levels or equivalent | 65 |
| Undergraduates | 123 |
| Postgraduates | 38 |
| Age Group | |
| 25 to 29 years old | 27 |
| 30 to 34 years old | 55 |
| 35 to 39 years old | 100 |
| 40 to 44 years old | 81 |
| 45 to 49 years old | 45 |
| 50 to 54 years old | 76 |
| Monthly Income Level | |
| Less than RM3,000 | 72 |
| RM3,000 to RM5,000 | 143 |
| RM5,000 to RM10,000 | 152 |
| More than RM10,000 | 17 |

RELIABILITY STATISTICS AND MEAN SCORE

Table 3 provides information about the internal consistency of the four variables measured in a study, including the well-being of married adults, marital satisfaction, family support and psychological distress. The table shows the number of items included in each variable and in this case, the Cronbach's alpha values for all variables are high, ranging from 0.91 for well-being to 0.961. Together, the mean scores for each variable were computed, along with their standard deviations. The results showed that the mean score for the variables ranging from 3.73 to 3.80 and psychological distress was 2.06.

| Variables | Mean Score | Standard Deviation | No of Items | Cronbach's Alpha value |
|------------------------------|------------|--------------------|-------------|------------------------|
| Well-Being of Married Adults | 3.81 | .66 | 8 | 0.91 |
| Marital Satisfaction | 3.73 | .84 | 6 | 0.96 |
| Family Support | 3.77 | .73 | 6 | 0.96 |
| Psychological Distress | 2.06 | .81 | 7 | 0.93 |

RESULT OF PEARSON CORRELATION AMONG THE INDEPENDENT AND DEPENDENT VARIABLES

The correlation table presented below shows the Pearson correlation coefficients between four variables: For each pair of variables, the table provides the correlation coefficient, which ranges from -1 to 1 and measures the strength and direction of the linear relationship between the two variables. The significance level of the correlation coefficient is also provided in the Table 4. An asterisk next to the coefficient indicates that the correlation is statistically significant at the 0.01 level (two-tailed), meaning that there is less than a 1% chance that the observed correlation could have occurred by chance.

In this case, the correlation coefficient between the well-being of the married adults' variables and the marital satisfaction variable is 0.35**, which indicates a moderate positive correlation between the two variables. This suggests that higher levels of marital satisfaction are associated with higher levels of well-being in married life.

Similarly, the correlation coefficient between the well-being of married adults and the family support variable is 0.25**, indicating a moderate positive correlation between the two variables. This suggests that higher levels of family support are associated with higher levels of well-being in married life. On the other hand, the well-being of married adults is negatively correlated with psychological distress ($r = -0.50^{**}$), indicating that people with lower distress scores indicate higher well-being in their married life (Table 4).

| Variable | Well-Being of Married Adults |
|------------------------|------------------------------|
| Marital Satisfaction | 0.35** |
| Family Support | 0.25** |
| Psychological Distress | -0.50** |

** Correlation is significant at the 0.01 level (two-tailed)

RESULTS OF REGRESSION ANALYSIS

The Table 5 below shows the summary statistics for a linear regression model with four variables: well-being of married adults (dependent variable) and three independent variables (psychological distress, marital satisfaction, and family support). The multiple correlation coefficient (R) of the model is 0.56, indicating a moderate positive correlation between the dependent variable and the independent variables. The coefficient of determination (R Square) is 0.32, which means that the independent variables explain about 31.7% of the variance in the dependent variable. The adjusted R Square value, which takes into account the number of independent variables in the model and adjusts the R Square value accordingly, is 0.31. The standard error of the estimate, which measures the average distance between the observed values of the dependent variable and the predicted values from the model, is 0.55.

These statistics can be used to evaluate how well the model fits the data and to make predictions about the dependent variable based on the independent variables. In this case, the model suggests that the three independent variables, psychological distress, marital satisfaction, and family support, are moderately predictive of well-being of married adults, explaining about 31.7% of the variance in the dependent variable.

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|------|----------|-------------------|----------------------------|
| 1 | 0.56 | 0.32 | 0.31 | 0.55 |

The regression coefficients for each of the independent variables provide information on the strength and direction of their relationship with the dependent (Table 6). The coefficient for the constant is 3.60, which represents the expected value of the dependent variable (well-being of married adults) when all independent variables are equal to zero. The findings indicated that, when the score of marital satisfaction is increase by 0.18 and psychological distress score decrease by -0.36 unit, the well-being of married adults in this study will increased by 1 unit. Specifically, from the Table 6, marital satisfaction has a positive and statistically significant effect on the well-being of married adults (B = 0.18, t = 5.07, p < 0.01) and psychological distress has a statistically negative significant effect on the well-being of married adults (B = -0.36, t = -9.70, p < 0.01).

| Variable | Unstandardized Coefficients (B) | Standard Error | t-value | Sig. |
|------------------------|---------------------------------|----------------|---------|-------|
| (Constant) | 3.60 | 0.22 | 16.75 | 0.000 |
| Marital Satisfaction | 0.18 | 0.04 | 5.07 | 0.000 |
| Family Support | 0.07 | 0.04 | 1.74 | 0.080 |
| Psychological Distress | -0.36 | 0.04 | -9.70 | 0.000 |

DISCUSSION OF THE RESULT

The present study aimed to examine the relationship between marital satisfaction, family support, psychological distress, and well-being among married adults in Petaling Jaya, Selangor. The findings of the study indicate that based on the final model used, marital satisfaction and psychological distress have significant effects on the well-being of married adults, while the effect of family support is not statistically significant. The mean scores analysis indicated that the participants had moderate levels of well-being, marital satisfaction, and family support, while their psychological distress was low. These results are consistent with previous research on marital and family relationships, which suggests that marital satisfaction and family support are important for promoting individual and family well-being (Proulx et al., 2007).

The correlation analysis revealed a positive and significant relationship between well-being and marital satisfaction and family support. These findings support previous research indicating that individuals who are satisfied with their marriages and receive social support from their families are more likely to experience greater well-being (Kiecolt-Glaser & Newton, 2001; Thoits, 2011). The study found that psychological distress has a significant negative impact on the well-being of married adults. Specifically, individuals experiencing lower levels of psychological distress were associated with higher levels of well-being. This finding is consistent with previous research. For example, a study by Kessler et al. (2010) found that psychological distress was associated with lower levels of life satisfaction and happiness. Couples who experience higher levels of psychological distress are more likely to experience negative emotions, communicate poorly, and experience more conflicts, all of which can lead to a lower sense of well-being in their marriage. Therefore, interventions aimed at reducing psychological distress may be effective in promoting well-being in married couples.

The negative correlation between psychological distress and well-being is also consistent with prior research indicating that individuals experiencing high levels of psychological distress are more likely to experience reduced well-being and poorer health outcomes (Keyes, 2007). The results suggest that interventions aimed at reducing psychological distress in married adults may be essential in promoting their well-being. These interventions may include psychotherapy, cognitive-behavioural therapy, or mindfulness-based interventions, among others.

However, while the correlation analysis suggested that family support was positively related to well-being, the effect was not statistically significant in the regression analysis. This suggests that family support may not be a significant predictor of well-being among married adults in Petaling Jaya, Selangor. This finding is somewhat surprising, as previous research has suggested that the quality of family relationships, including social support (e.g., providing love, advice, and care) and strain (e.g., arguments, being critical, making too many demands), can influence well-being through psychosocial, behavioural, and physiological pathways (Thomas et al., 2017). However, it is important to note that this study did not take into account the broader context in which family support operates, family support can take various forms, such as emotional support, practical support and financial support, which may impact well-being differently.

The results revealed that marital satisfaction was positively related to well-being, indicating that individuals who reported higher levels of marital satisfaction also experienced higher levels of well-being. The finding that marital satisfaction has a positive effect on the well-being of married adults is consistent with previous research. For example, a study by Bradbury and Karney (2010) found that marital satisfaction was a strong predictor of overall well-being in married individuals. According to Fincham and Steven (2010), marital satisfaction is a key predictor of well-being among married individuals. They argue that individuals who are satisfied with their marriage tend to have better physical and mental health than those who are not satisfied with their marriage.

Couples who feel satisfied with their marriage are more likely to experience positive emotions, have fewer conflicts, and communicate more effectively. This finding is also consistent with previous research indicating that Marital Satisfaction is an important predictor of overall marital quality and well-

being (Kline et al., 2021). Higher levels of Marital Satisfaction suggest that couples feel more connected to each other, have greater intimacy, and experience fewer conflicts, all of which contribute to a greater sense of well-being in their marriage. Therefore, interventions aimed at improving Marital Satisfaction may be effective in promoting well-being in married couples.

For the hypothesis, the findings of this study provide support for the idea that marital satisfaction is significantly related to well-being among married adults, as indicated by the rejection of the null hypothesis for Hypothesis 1. This result is consistent with previous research that has shown a positive relationship between marital satisfaction and well-being (Booth, Johnson, White, & Edwards, 1984; Dyrda & Lucas, 2013). As for the Hypothesis 2 was also supported, indicating that there is a significant relationship between family support and well-being among married adults. This finding is supported the previous research that has suggested that family support can be an important predictor of well-being (Barnett & Gotlib, 1988). Hypothesis 3 predicted that there is no significant relationship between psychological distress and well-being among married adults. The null hypothesis was rejected, indicating that there is a negative relationship between psychological distress and well-being among married adults. This finding is consistent with previous research that has shown a strong negative association between psychological distress and well-being (Krause, 2003). Finally, the results of Hypothesis 4 indicate that there is a significant model in explaining the well-being among married adults in this study. This finding suggests that these factors may interact with each other in complex ways to influence overall well-being. Previous research has also highlighted the importance of examining multiple predictors of well-being simultaneously (Diener & Seligman, 2004; Diener, Suh, Lucas, & Smith, 1999).

It is worth noting that other factors, such as demographic and cultural factors, may also play a role in the relationship between the independent variables and the well-being of married adults. It is important to consider the broader context in which these variables operate and how they may interact with other factors to impact well-being in a marriage. Overall, the findings of this study suggest that marital satisfaction and psychological distress are important predictors of the well-being of married adults. Therefore, interventions aimed at improving marital satisfaction and reducing psychological distress may be effective in promoting overall well-being in married couples. However, further research is needed to better understand the complex relationships between these factors and to identify other important predictors of marital well-being.

The results of this study contribute to our understanding of the factors that influence the well-being of married adults. The findings are consistent with the existing literature that highlights the importance of marital satisfaction and psychological distress in predicting well-being. The study also adds to the literature by exploring the role of family support in the well-being of married adults. Although the effect of family support on well-being was non-significant, this finding highlights the need for further research to investigate the relationships between family support and well-being, particularly in the context of marital relationships. Furthermore, the study contributes to the development of theoretical models that explain the mechanisms underlying the relationships between these variables. For example, the findings suggest that marital satisfaction may influence well-being through its effect on psychological distress, as individuals who are more satisfied with their marital relationships may experience less psychological distress, which in turn, may contribute to higher levels of well-being.

The findings have implications for the development of policies and programs that aim to support married adults. By implementing policies such as the Mental Health Policy and Action Plan, the National Family Policy, and the Women Empowerment Policy, the government can promote access to mental health services and improve family support. These policies can contribute to reducing psychological distress and promoting well-being among married adults. In addition to policies, programs such as the Family Support Program, Marriage and Family Therapy Program, Affordable Childcare Program, and Flexible Work Arrangements Program can also support married adults in improving their psychological well-being and overall quality of life.

CONCLUSION

This study provides important insights into the relationship between marital satisfaction, family support, psychological distress, and well-being among married adults in Petaling Jaya, Selangor. The first objective of the study is to determine the relationship between marital satisfaction, family support and psychological distress towards well-being among married adults in Petaling Jaya, Selangor.

The study findings reveal that marital satisfaction is a significant predictor of well-being among married adults. In other words, higher levels of marital satisfaction are associated with a higher level of well-being. On the other hand, family support has a positive effect on the well-being of married adults, but this effect is not statistically significant. This suggests that family support may not be as important as marital satisfaction in contributing to the well-being of married adults. Additionally, psychological distress was found to have a significant negative effect on well-being, indicating that lower levels of psychological distress are associated with higher levels of well-being in married adults. This study highlights the importance of addressing psychological distress in promoting the well-being of married adults. The findings suggest that psychological distress is a significant factor that can impact the well-being of married adults in Petaling Jaya, Selangor. Therefore, it is essential to develop interventions and strategies to reduce psychological distress and promote mental health and well-being in married adults.

Other than that, the finding suggest that marital satisfaction and psychological distress are significant predictors of well-being model among married adults in Petaling Jaya, Selangor. This indicates that individuals who report higher levels of marital satisfaction and lower levels of psychological distress are more likely to experience higher levels of well-being. The finding that psychological distress is a significant predictor of well-being among married adults highlights the importance of addressing mental health issues in promoting overall well-being. Psychological distress can stem from various factors such as anxiety, depression, and stress and can significantly impact an individual's well-being. Interventions aimed at reducing psychological distress, such as therapy or stress-management programs, may be effective in improving the well-being of married adults. Therefore, it is important to prioritize and support mental health interventions to address psychological distress among married adults, promoting their overall well-being.

The effect of family support on well-being was not found to be statistically significant, indicating that other factors may play a more important role in predicting well-being among married adults in Petaling Jaya, Selangor. Overall, the findings suggest that marital satisfaction and psychological distress are important predictors of well-being among married adults, and interventions that focus on improving marital satisfaction and reducing psychological distress may be effective in promoting well-being among this population. Social support towards other people well-being has also been studied in past studies in various area of study (Hossain, Mustapha & Amirrudin, 2020; Zakaria & Jaafar, 2021; Zhihao & Mustapha, 2021; Jaafar, Abidin, Kamarudin, & Zakaria, 2021).

There are two limitations that apply to this study. Firstly, the study used a convenience sampling method, which may not have represented the broader population of married adults in Petaling Jaya, Selangor. The sample may have been biased towards individuals who were more willing or available to participate, potentially limiting the generalizability of the findings. Finally, the study was limited to married adults in Petaling Jaya, Selangor, which may not be representative of other regions or cultural contexts. The findings may only be applicable within the specific cultural and geographic context in which the study was conducted.

Despite the limitations, this study on the relationship between marital satisfaction, family support, psychological distress, and well-being among married adults in Petaling Jaya, Selangor, has important implications for the development of interventions, policies, and programs that can promote the well-being of married adults. The findings of this study suggest that interventions that focus on improving marital satisfaction and reducing psychological distress may be effective in promoting well-being among married adults. For example, interventions that target couples' communication skills, conflict resolution strategies, and shared decision-making may improve marital satisfaction, which can contribute to higher

levels of well-being. Additionally, interventions that target the reduction of psychological distress, such as cognitive-behavioural therapy, mindfulness-based interventions, and stress management programs, may also be effective in promoting well-being.

Based on the findings and limitations of the study, there are several recommendations for future research that could contribute to a more comprehensive understanding of the relationship between marital satisfaction, family support, psychological distress, and well-being among married adults in Petaling Jaya, Selangor. Firstly, developing and implementing interventions that focus on improving marital satisfaction and family support among married adults could be beneficial. These interventions may include counselling services, workshops, or educational programs. Educating married adults on the importance of mental health and well-being could also be helpful in raising awareness and providing resources and support for those experiencing mental health challenges.

Secondly, further research is needed to better understand the complex relationships between marital satisfaction, family support, psychological distress, and well-being among married adults. Future studies could examine the impact of additional factors such as culture, religion, and social support on these relationships. Finally, the result could help in developing and implementing programs that focus on strengthening the social support networks of married adults, particularly in urban settings where individuals may feel isolated or disconnected from their communities. These programs could include community-based activities, support groups, or other initiatives that encourage social interaction and connection.

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INFLUENCE OF GOVERNMENT POLICIES ON THE PROVISION OF PUBLIC INFRASTRUCTURE IN ILA FEDERAL CONSTITUENCY OF OSUN STATE, NIGERIA

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ABSTRACT

This study examined the distribution pattern of selected infrastructure in Ila federal constituency of Osun state, Nigeria. Primary data will be derived from focus group discussions (FGD) with the villagers, oral interviews, personal and participant observations at field work location and questionnaire administration. Participant Observation at field work location was included in this research as part of the process of data collection during fieldwork. Questionnaire was administered to the rural residents on household basis. Secondary data was obtained from relevant local, state, federal and international publications. Data on the population of the study areas was obtained from the National Population Commission (NPC), while maps of the study area were collected from Osun State Ministry of Lands and Physical Planning in conjunction with Goggle map. The variation in road conditions highlights the significance of regular maintenance endeavors to uphold the quality and safety of these crucial transportation routes. Both primary and secondary data were utilized for this study. Findings revealed that the state of tarred roads displays a diverse topography. Furthermore, findings established that majority (53.2%) o the roads in the study area exhibit consistently level and even surfaces, while a significant 10.2% display signs of deterioration characterized by the presence of potholes and uneven sections. The policy implications of this study's finding suggest that while urban residents should have access to a suitable house- type that fulfills their housing needs and aspirations, the quality of urban housing, and by extension, the quality of life for urban residents, can be enhanced if urgent attention is paid by government to the provision of basic social amenities and infrastructural facilities.

Keywords:

Infrastructure, Resources, Facilities, Development, Ila

INTRODUCTION

Infrastructure has been widely accepted as one of the factors in the development of any country. Kessides (2004) maintained that infrastructure is a prerequisite to support the development process of any nation. Wijesinghe and Thorn (2021) sees infrastructure as the basic requirement for the functionality of human settlement. Studies such as World Bank, 2018; Govinda, Gal and Song 2020; Calderon 2009; Egbetokun 2009; Manggut *et al*, 2018; Yoade, Olanrewaju and Adeyemi, 2020) have shown that infrastructure has a good impact on the quality of social services especially in the area of education, health, water and quality of rural life in general. The World Bank Development Indicators Report also affirmed that infrastructure such as communication, road, electricity, port, railway, airport, water supply form the foundation for industrialization and infrastructure development (World Bank, 2016; Yi Huan & Golnoosh Manteghi, 2022). Infrastructure is very crucial to both national and regional development, Ajanlekoko (2016), Zhou *et al* (2017), Adewoye (2015), Sambo, Subair and Oke (2018) identified housing to be crucial to public health, transportation enhances rural-urban integration and foreign trade and electricity infrastructure provides bases for commercial activities and technological advancement. Familoni (2016) maintained that education infrastructure is crucial to human capacity development, improved health productivity and access to paid employments.

Barios (2008) also observed that public demand for improved infrastructure both in quality and quantity has expanded in many countries in line with increased economic activity in rural areas. However, rural areas experience slower progress and less attention from government than urban areas. This has resulted in the lower availability of services for rural people. The shortage of infrastructure as the barrier in optimizing the potential benefits of local resources to the economic activities in the rural areas has been considered by researchers such as Pinstrup-Anderson & Shimokawa, 2008; and Agenor, 2008. The slow pace of rural infrastructure development has to a greater extent been a challenge to rural development in Ila Federal Constituency of Nigeria which is predominantly dominated by agrarian people and a lot of agricultural resources which are germane to national development. Another challenge to rural infrastructure development is that a rural economy project is mostly considered to be a government intervention than a private sector investment (Onifade, Yoade, Olatunji, & Husseni, 2023). Also, rural infrastructure projects such as road, electricity and water supply focus on free public facilities rather than commercial public facilities. Furthermore, the state of infrastructure in Osun State shows that the available infrastructure is either inadequate to serve the people or they are not performing to their optimal level.

The successive governments in Nigeria have initiated a lot of programs and policies to improve the quality of people's life both in urban and rural areas. Among such programs are Agricultural Development Projects (ADP's), Directorate of Food, Roads and Rural Infrastructures (DFRRI), River Basin Development Authority (RBDA), and of recent the National Fadama Development Project (NFDP) initiated purposely to better the life of the people be it rural or urban. This shows that the development of infrastructure such as road, electricity project, basic medical facilities, water supply and educational facilities had been identified as key to rural development in Nigeria (Yoade, 2022).

Generally, infrastructure provision is the act of supplying facilities with the aim of ensuring their availability and adequacy for the users. According to Sozuer and Spang (2012), infrastructure provision is a process of financing, construction of structures, renovation of facilities, and the delivery of attendant services by government, international donors, and independent organizations. Infrastructure provision connotes the utilization of infrastructure and assessing derivable benefits to the users serving as the beneficiaries of the provision (Ajayi and Omole, 2012; Olatunji & Yoade, 2022). It is concerned with meeting the infrastructure demand of the people and sustainability of such infrastructure in order to continually fulfill the purpose for which they are provided. From the foregoing, this study is concerned with examining the provision of public infrastructure facilities in the rural areas of Ifedayo, Ila and Boluwaduro Local Government Areas that made up Ila Federal Constituency. The study will provide information on the impact of the facilities on socio-economic activities in Ila Federal Constituency which could serve as a framework for policy formulation for the enhancement of socio-economic well-being of the residents in rural areas.

THE STUDY AREA

Ila Federal Constituency is located between latitudes $8^{\circ} 01' 1.70''$ N and longitude $4^{\circ} 54' 15.16''$ E. It is located in North Eastern part of Osun State. It is bordered in the North East by Ekiti State, South East by Ondo State, South West by Ogun State and in the North West by Oyo State. Figure 1 shows Ila Federal Constituency within the context of Osun State. Ila Federal Constituency is made up of three Local Government Area namely Boluwaduro, Ifedayo and Ila Local Government (Figure 1).

According to the 2006 National Population Census, Ifedayo Local Government with headquarters in Oke-Ila Orangun had a population of 40,560, Ila with the headquarters in Ila-Orangun had a population of 67,410 and Boluwaduro with headquarters in Otan Ayegbaju had a population of 76,890. In the state, a rural local government council is defined as a council area with only one or two small towns as the principal settlements while the remaining settlements are rural communities. The three Local Government Council Areas have two small towns as the principal settlements except Ila Orangun

which is largely urban with population of over 67,000 people of which the surrounding communities are rural areas. The huge number of rural settlements serves as the major reason for choosing that federal constituency as the study area. Majority of the people in both urban and rural settlement of the Local Government are farmers. Migrants' farmers from other parts of Nigeria (including Ibadan, Benin, Otun Ekiti, Ipoti Ekiti, Igogo, Ore, Akure, Osogbo, Ikirun, Okuku, Inisa and those within the local government) tends to influence the rapid agricultural developments in the area (Agboola 1979, Olajuyin and Fadare, 1987). Most of the basic infrastructures available in the study area are health, road transport, education, and water and electricity facilities. This study will focus on the analysis of road transport, water supply and electricity facilities.

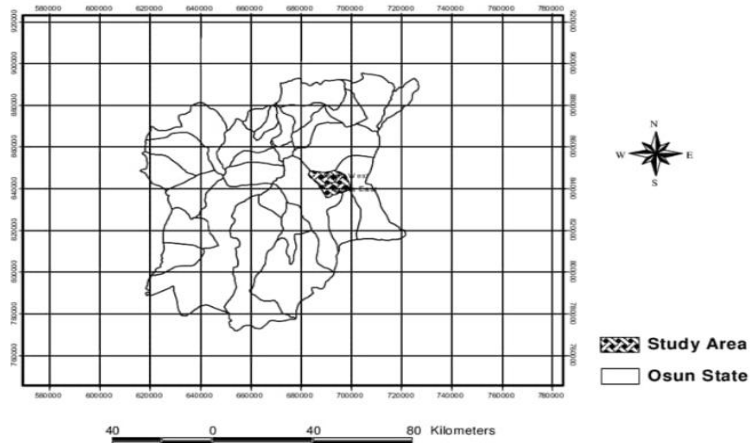


Figure 1. Ila Federal Constituency within Osun State

LITERATURE REVIEW

According to Spacy (2018), infrastructure provision in the guise of facility is the creation and enhancement of the basic services with the goal of promoting economic growth and increasing people's quality of life. However, the utilization and availability of infrastructure in a particular system or a geographical confine connotes development. Development according to Friedmann (1976) is the innovation process that leads to transformation of a social system which manifests in social overhead capital (SOC). It furthered that the social overhead capital is termed infrastructure which brings about innovations within a social system. The social system in the context of this study is rural areas. Rural areas are a form of community of people that is mainly for agrarian development. Thus, infrastructure facilities are very inconsequential in the development of rural area. The services derived from infrastructure tame development in the various communities of people.

Infrastructure is the required basic service to be set up that allows development to thrive. However, infrastructure facilities boost economic development in any nation. The absence of required infrastructure facilities in a nation is dangerous both to the economy and well-being of individuals in such a place. The provision of facilities in the various sectors of the of the development has being the focus of nations, it is a task that involves theoretical analysis and empirical studies that could accentuates decision makers towards action plans (Nedozi et al., 2014).

Ogunlana, Yakubu and Aihassan (2016) examined infrastructural finance and development in Nigeria between (1970 – 2014), the study analyses the effect of public and private investment on infrastructures and its impact on economic growth based on the empirical review of Stephane et al (2007) and Sahoo et al (2010) approach to explain the effect of public and private investment in infrastructure

with its impact on economic growth. The work carried out based on the gap that there are only few studies to have investigated infrastructure development using varieties of outcomes to gauge growth and development showed that the only avenue a country can explore to attain a reasonable potential is to commit resources to the provision of infrastructures such as good roads, functional railway system, water, electricity, schools, housing etc.

The result however detects that domestic investment on infrastructure and total labour force correlated with economic growth negatively; that Nigeria's experience in terms of infrastructure development show that government needs to design an economic policy that would raise the quality of infrastructure. It was concluded that the reasons for the deplorable conditions of infrastructures among others are; reduction in government spending on its provision, vandalizing of the existing ones, corruption, bureaucratic bottlenecks and delay in or poor maintenance and repairs of damaged facilities (Yoade and Olatunji, 2022).

Similarly, Edun, Akinde and Olaleye (2013) and Owolabi Merus (2015) both investigated the Nigerian perspective on infrastructural development and its effect on economic growth. The studies nexus between the two variables and attempted to bring to the fore because under investment in infrastructural development can lead to economic growth without economic development used the economic model with foreign investment to examine the impact of increase in labour on production of private goods, public infrastructure, foreign investment, welfare and complete specialization. From the study, it was deduced that relatively the neglect of infrastructure has negative effect on the economy, for example; increase in cost of raw materials, reduction of productivity and competitiveness of firms, shrinkage of Foreign Direct Investment (FDI) as investors will always flood or relocate to countries where there is abundant infrastructural facilities. The study concluded that there is a robust relationship between foreign direct investment and infrastructural development.

Rufus et al (2017) analyzed critical infrastructure decay and development crises in Nigeria by investigating comparatively the critical nature of infrastructure to the overall development of the nation vis-avis other developed societies the broad objective of which was to identify the missing link and its prospects. The theoretical framework adopted for the study is the Structural Functional Analysis Theory by Gabriel Almond which is fundamentally concerned with the phenomenon of system maintenance and regulations. The study justified how maintenance and stability of our infrastructure can enhance sustainable development to boost the economy of the nation. The study concluded that there is a disconnect between public and private sector in sustainable infrastructure development and that critical infrastructure should not be taken with levity and neglect if the nation must break out of the dialectical cycle of infrastructure development crises.

In addition, Gbadebo and Olalusi (2014) also identified the critical factors affecting the development of infrastructure in Nigeria. The study which looked into the challenges of the sector using empirical review of literature from scholars shows that infrastructure contributes to the economic development by increasing productivity and providing amenities which enhances the quality of life. The research which recommended that experts in infrastructure development should embrace infrastructural technology skills and methodology identified dearth of visionary leaders, capital flight, capital stagnancy, corruption etc. as some of the factors affecting development of infrastructure in the country. Also, Orji, Worika and Umofia (2017) explored the impact of infrastructural development on Nigeria's industrial sector. The study with empirical review of data on time series spanning 1990-2015 used ordinary least square method of regression analysis to investigate the industry value-added (% of GDP) as an indicator of industrial sector performances and also using the index of electricity consumption, gross capital formation and federal government spending on transport and communication as an indicator for infrastructure development. The result of the regression showed that the index of electricity consumption exerted a positive but significant impact on industry value-added and that federal government spending had a negative but significant impact on industry value-added. It was recommended that measures to revamp and maintain the power sector in Nigeria must be taken seriously to ensure better and steady supply of electricity.

Furthermore, in a study on the challenges of infrastructure development in democratic governance, Oyedele (2012) carried out an empirical review of literature by tracing the era from the independence. The study showed the impact of military regimes with unquestionable attitude by using decree and giving no room for citizens' participation in decision making. The study also identified the impact of civil war which turned Nigeria against one another with the huge sum of money that could have been used to better the lot of the people been used to prosecute the needless war. The researcher noted that demand for infrastructure is higher and resources used in providing them are limited. It was concluded that infrastructure development in democratic governance involves identifying the right project, carrying out feasibility studies and carrying out the physical development of the project

Moreover, in a study conducted by Kaur and Kaur (2018), on the role of social and economic infrastructure in economic development of Punjab, India between 2001-2016 noted that expenditure on education, training & research and improvement of health contributes to increase in quality of population and hence improved productivity. The study which uses multiple regression models for analyzing the impact of social infrastructure viz. education, health and economic infrastructure on the Net State Domestic Product (NSDP) per capita. The study revealed that there exists a significant impact of the health infrastructure index and the economic infrastructure index on the economic development; also, there exist a insignificant impact of education infrastructure index on the economic development of Punjab. The study concluded that economic infrastructure has shown better growth as compare to social infrastructure.

CONCEPTUAL FRAMEWORK FOR THE STUDY

The conceptual framework for this study is derived from the literature review and theoretical framework. It will serve as a guide for data collection and investigation of variation can be determined. It has been pointed out in the background that this study will examine the provision of public infrastructure (road, electricity, water) in the area of stakeholder responsible for the provision of infrastructure. Major stakeholders are Government, Non-Governmental Organization (NGOs), Community Development Association.

The state of the existing public infrastructure can also be viewed on the major provider of the facilities in order to know who will be responsible for the financing, maintenance, and renovation to prevent failures when the infrastructure has failed its functions. The development of appropriate rural infrastructure maintenance systems will help to monitor the condition of the infrastructure through inspection and identification of the priority task to minimize the total cost of keeping the infrastructure functioning.

The condition of existing infrastructure can be viewed in the area of adequacy, functionality, availability, accessibility and spatial distribution of the existing infrastructure whether the locational pattern is clustered or dispersed. The various factors that can influence in the condition of the existing infrastructure are inadequate government intervention, no sense of ownership by stakeholders, inadequate funding, vandalism, overcrowding, differed maintenance, among others.

However, adequacy of the infrastructure available can be viewed from the quality of service rendered, availability of demand and supply, satisfaction derived can be viewed from service rendered, distance covered, availability, adequacy and accessibility. Furthermore, factors that influence infrastructure provision are political instability, state of the nation economy, security, government policy and corruption.

From the rural economic growth and development point of view, rural infrastructure like roads, electricity and water supply provides the necessary prerequisites for growth of agricultural and non-farm opportunities in rural areas. A lot of studies demonstrate that the provision of serviceable roads, electricity and water supply not only increase agriculture productivity; it also reduces the cost of inputs and outputs, encourages greater use of efficiency and generating technologies (Binswanger et al, 1987; Barnas and

Binswanger, 1984), but also support the emergence of small businesses in rural areas which can be a significant source of improvement in rural economic activities in the area of employment opportunities and income for the poor, achievement of sustainable development goal and free flow of goods and service (Binswanger, Khandker and Rosenzweig 1989; Lamach et al 2000).

Infrastructure provision supports the rural economy by developing market access and supporting market expansion for the exchange of goods and services (Yao 2003). It does not only involve the physical flow of goods and services, but also information about commodity price, and market information among the community such as work of transport and communication services (Figure 2). The role of infrastructure provision provides a strong justification for the governments to finance guaranteed infrastructure maintenance and renovation in Ila Federal Constituency.

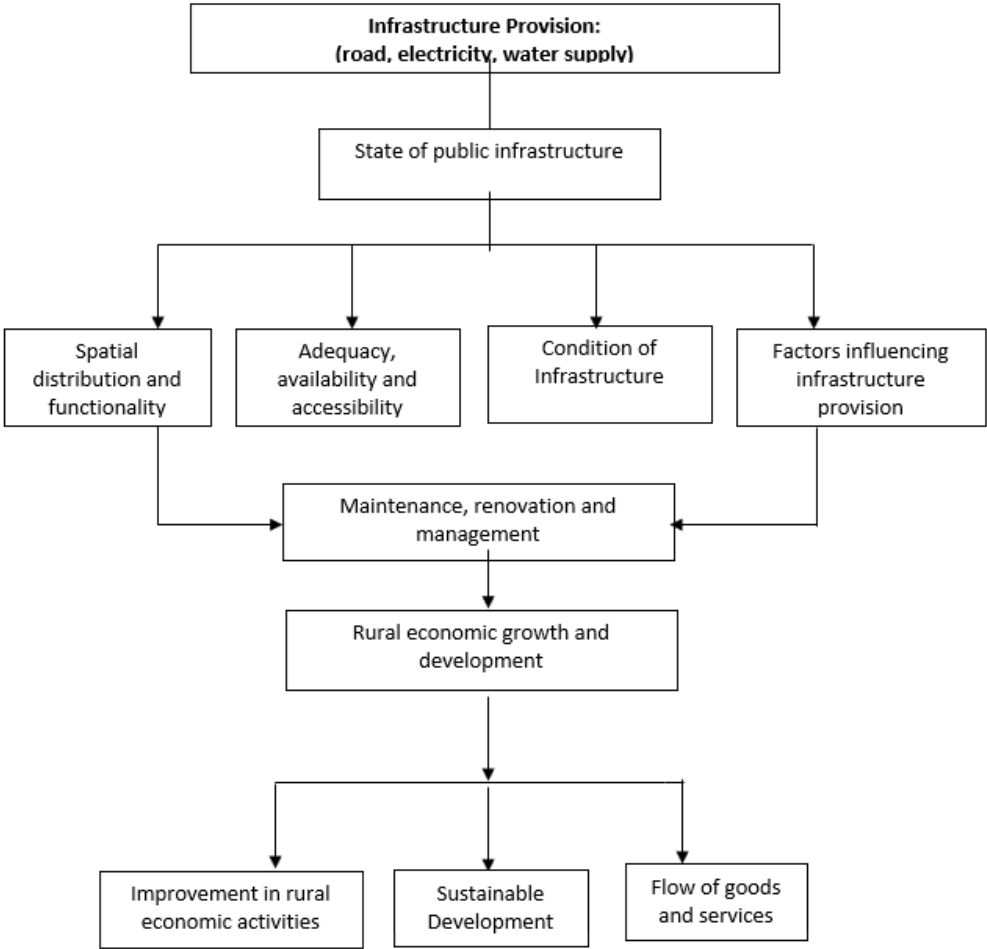


Figure 2: A simple framework illustrating the link between infrastructure investment, state of public infrastructure maintenance and management and rural economic growth and development

RESEARCH METHODOLOGY

Both primary and secondary data were utilized for this study. Primary data will be derived from the focus group discussions (FGD) with the villagers, oral interviews, personal and participant observations at field work location and questionnaire administration. THE FGD is in a form of group interview where the aim is to understand the social dynamic and interaction between the participants through the collection of verbal and observational data. Oral interviews with government officials will be carried out using face to face interview with the key decision makers in the local government level. The aim of these interviews is to identify the government policy on infrastructure and rural development programs.

Interviews with the key decision makers in rural development and rural infrastructure policies were conducted in the early stages of field research in order to gain a comprehensive understanding of infrastructure utilization in specific areas from knowledgeable stakeholders. Participant Observation at field work location was included in this research as part of the process of data collection during fieldwork. Participant observation is a useful tool that enriches the data and information collected by the researcher (Yin 2015). Questionnaire was administered to the rural residents on household basis.

Secondary data was obtained from relevant local, state, federal and international publications. Data on the population of the study areas was obtained from the National Population Commission (NPC), while maps of the study area will be collected from Osun State Ministry of Lands and Physical Planning in conjunction with Goggle map. Other relevant information will be collected from documentary report, newspaper, magazines, thesis, dissertations, seminar papers, journals and internet resources to enrich the research. Various agencies and parastatals of Osun state will be visited for information on Rural Water Environmental Sanitation Agency (RUWESA), Osun Rural Access and Mobility Project (O'RAMP), Ministry of work and transport, National Bureau of statistics (NBS), Ibadan Electricity Distribution Company, Osogbo (IBDEC), Osun Rural Enterprise and Agriculture Programme (O'REAP).

Focus group discussion methods are used to explore the local community perceptions about the role infrastructure plays in their economic activity. The analysis of focus group interview transcripts and observation data revealed a number of key findings related to participants experiences of economic activity in relation to rural infrastructure. It also included discussion on the relationship between sustainable rural developments and sustainable infrastructure, problems and challenges faced by local people in term of their economic activities, the adaptation process of the local community in maximizing benefits from available infrastructure and future development needs of the local community to support their rural economies.

RESULT AND DISCUSSION

Major Stakeholder in Infrastructure Development of the Study Area Preamble

This study is intended at presenting the result of findings from the study on the influence of government policies on the provision of public infrastructure in Ila federal constituency. Agboola (1998) defined policy as plan actions, a statement of aim, idea or statement intents made to guide activities in the field of endeavors. Therefore, government policy are written which usually comprises specific objective strategies and programs aimed at solving specific problems of the people or meeting with ever increasing needs of the people (Ezenagu, 1990). Government policy in the context of political terrain in Nigeria has dimensionally influenced the provision of infrastructure. The study of udoka (2014) decried the deplorable conditions of infrastructure development occasioned by neglect from the governments; this has caused economic doldrums in most towns and cities in Akwa Ibom State. The policy that will ensure its adequate provisioning is missing and partly because politics is affecting its provision. Ethnic interest agitation and lobbying for infrastructure provision are common things in multi – ethnic state like Nigeria. Most infrastructures are now decayed and need repair or replacement.

However, Government is the system that plans, organizes, control and supervises the people who are resident in an area in other for all to have serene environment for living and a sense of belonging. Government has the power to put in place all measures that it deem fit will make an environment beneficial for living for everybody. Politics of infrastructure provisioning in Nigeria can best be understood viewing Nigeria in four different areas; Pre – Independence, Post – Independence, under Military rule and under Democratic rule. Pre – Independence, the colonial masters provided infrastructure based on politics to ensure that the elites were comfortable and to ensure easy evacuation of goods out of Nigeria.

Nigeria became a federal republic in 1963 and began democratic governance. This era marked the best period for infrastructure provision in Nigeria as the leaders in the three regions that made up Nigeria which are South West, East and North competed successfully for infrastructure provision. The first republic was truncated by the military coup d'état of January 15, 1966. The military regime that came in struggled for most of the time for legitimacy. There was little infrastructure development. The second republic started in August 1979 and was ended by another military take – over in December 1983. The Third republic that started in December 1990 was truncated by General Badamosi Babangida on June 12, 1993. Policies are bases upon which good governance are based. The fourth republic and the current democracy started on May 29, 1999. The United States Government and the Federal Government are to partner on a project that will address infrastructure deficit in the country

Government Policy in Infrastructure Provision

The made an attempt to understand the role of government policy on the provision of public infrastructure and responses were returned by the respondents is presented in table 1. However, they were asked to rank the influence of the policy on the provision base on excellent, good, fair and poor hierarchy, the result of the response was presented as follows. In Boluwaduro local government area, 154 respondents were sampled, among which 76.6% of the respondents only see the influence of the government policy in the provision of infrastructure as fair and 23.4% of the respondents deem it good, whereas none of the respondents can rank the influence of government policy in the provision of infrastructure as excellent or poor as they have 0% count respectively. The result of the findings gotten from Ifedayo local government area indicate that 65.2% of the respondents finds government policy influence in the provision of infrastructure fair in the area, while 33.8% of the respondents find the same good; however, 0.5% of the respondents finds the influence of government policy as the major stakeholder in the provision of infrastructure as excellent and poor respectively. For Ila local government area, 61.1% of the respondents agree that the influence of government policy in the provision of infrastructure is just fair whereas 38.9% of the respondents find it to be good, leaving no responses for either poor rating or excellent rating in Ila local government area.

Table 1: Government policy in Infrastructure Provision

| Local Government | Government | | | | Total |
|------------------|------------|-------------|-------------|----------|-------------|
| | Excellent | Good | Fair | Poor | |
| Bouwaduro | 0 (0.0%) | 36 (23.4%) | 118 (76.6%) | 0 (0.0%) | 154 (100%) |
| Ifedayo | 3(0.5%) | 205 (33.8%) | 396 (65.2%) | 3 (0.5%) | 607 (100%) |
| Ila | 0 (0.0%) | 257 (38.9%) | 404 (61.1%) | 0 (0.0%) | 661 (100%) |
| Total | 3 (0.2%) | 498 (35.0%) | 918 (35.0%) | 3 (0.2%) | 1422 (100%) |

Source: Fieldwork, 2023

Community Development Association Policy in Infrastructure Provision

The result of the finding on the influence of community development associations policy on infrastructure provision within Ila federal constituency was sought and table 2 present the findings. Across the study area, 65.7% of the respondents rank the influence of community development association policy in infrastructure provision as fair, while 34.2% rank it as fair and only 0.1% of the respondents rank their influence as excellent, where none of the respondents rank the influence of the community development association policy as poor in the study area. The breakdown of the influence on the influence of community development association policy has it that 83.0% of the respondents in Boluwaduro local government find it to be fair while 37.0% of the respondents rank it to be good but none of the respondents ranked it to either be excellent or poor respectively. In Ifedayo local government area, 66.4% of the respondents rate the influence of community development association policy in infrastructure provision as fair, 33.3% of the respondents rate it as good while 0.3% of the respondents rate it as excellent and it should be acknowledged that none of the respondents rate the influence of community development association policy as poor in Ifedayo local government area. In the same sequence, in Ila local government area 65.7% of the respondents rate the influence of community development association policy in infrastructure provision as fair, 34.3% of the respondents rate it as good and none of the respondents rate the influence as either poor or excellent.

Table 2: Community Development Association

| Local Government | Community Development Association | | | | |
|------------------|-----------------------------------|-------------|-------------|----------|-------------|
| | Excellent | Good | Fair | Poor | Total |
| Bouwaduro | 0 (0.0%) | 57 (37.0%) | 97 (83.0%) | 0 (0.0%) | 154 (100%) |
| Ifedayo | 2(0.3%) | 202 (33.3%) | 403 (66.4%) | 0 (0.0%) | 607 (100%) |
| Ila | 0 (0.0%) | 227 (34.3%) | 434 (65.7%) | 0 (0.0%) | 661 (100%) |
| Total | 2 (0.1%) | 486 (34.2%) | 934 (65.7%) | 0 (0.0%) | 1422 (100%) |

Source: Fieldwork, 2023

O’RAMP Policy in Infrastructure Provision

Osun Road Access Mobility Project (O’RAMP) as a major actor in the provision and management of infrastructure in Osun State was established with the sole purpose of improving the transportation of farm produce by farmers and linking them with accessibility to markets and industries. Ila Federal Constituency (Boluwaduro, Ifedayo, Ila Local Government) being an agrarian constituency is made up of many rural areas with vast farmland which needs accessible roads to allow the farmers in such communities to transport their farm produce to nearby markets for sale. Table 5.3 gives the details of the findings on the influence of O’RAMP Policy in Infrastructure Provision across Ila federal constituency. 55.7% of the respondents sees its policy as fair, 41.6% of the respondents sees it as good and only 2.6% of the respondents sees it as poor while none of the respondents see the influence of O’RAMP Policy in Infrastructure Provision as excellent in Ila federal constituency. On the breakdown of the influence across each local government area, table 3 reveals that 63.6% respondents see the activities of O’RAMP in Boluwaduro Local Government to be fair while 33.8% of the respondents see it to be good. The O’RAMP engage in the rehabilitation of Olukesi farm road, Ojueri, Iresi and construction of culvert over Obuke River in Boluwaduro Local Government. 2.6% respondents see the O’RAMP activities in the study area to be poor. In Ifedayo Local Government, 56.2% respondents see O’RAMP activities to be fair and 38.7% of the respondents see it to be good. 4.8% of the respondents see the activities in the study area to be poor. Actually, Osun Road Access Mobility Project (O’RAMP) carried out rehabilitation of road and

construction of culvert over rivers. O’RAMP helps in the construction of culvert on River Oyi Adunni at Oyin Adunni village on Ila Orangun – Oke Ila Orangun road in Ifedayo Local Government. They also rehabilitate that of Ayedaade and Ilupeju road both in Ifedayo Local Government. Osun RAMP met a lot of the rural roads in a state of disrepair, but the story has changed significantly as a lot of the roads are now wearing a look and farmers and traders now find it much easier to get to their farms. However, in Ila Local Government, 53.4% respondents see the activities of Rural Access Mobility Project to be fair while 46.1% of the respondents sees it to be good because construction and rehabilitation of roads was carried out for example Agbamu road was rehabilitated by O’RAMP to make it motorable. 0.5% respondents see their activities to be poor.

Table 3: O’RAMP Policy in Infrastructure Provision

| Local Government | O’RAMP | | | | |
|------------------|-----------|-------------|-------------|-----------|-------------|
| | Excellent | Good | Fair | Poor | Total |
| Boluwaduro | 0 (0.0%) | 52 (33.8%) | 98 (63.6%) | 4 (2.6%) | 154 (100%) |
| Ifedayo | 0 (0.0%) | 235 (38.7%) | 341 (56.2%) | 30 (4.9%) | 607 (100%) |
| Ila | 0 (0.0%) | 304 (46.1%) | 352 (53.4%) | 3 (0.5%) | 659 (100%) |
| Total | 0 (0.0%) | 59 (41.6%) | 791 (55.7%) | 37 (2.6%) | 1420 (100%) |

Source: Fieldwork, 2023

MAJOR STAKEHOLDERS IN INFRASTRUCTURE PROVISION

Road Transport Infrastructure

According to Udoka (2014), road transport refers to the conveyance of people, goods and services from one place to the other via roads. In almost rural areas in the study area, the road is the commonest means of transport (Fadare and Salami, 2004). Presented in table 4 is the finding on the major stakeholder on the provision of road infrastructure in Ila federal constituency. It could be noted that about 90.2% of the respondents agree that government is the major actor in the provision of road infrastructure in the area, followed by community development associations with 7.2% and self-help projects with 2.3% and lastly followed by well spirited individuals with 0.1% of the respondents. Based on each local government area that made Ila federal constituency, 90.9% of the respondents in Boluwaduro revealed that government and its agencies are the major provider of road infrastructure in the local government, 7.7% of the respondents stated that community development associations contribute to the provision of road infrastructure in the area while 2.3% of the respondents pinned it on self-help project, where no record was made for well spirited individuals in the provision of road infrastructure in the area. On the other hand, in Ifedayo local government area, 93.4% of the respondents agree to government being their major stakeholder in the provision of road infrastructure, 3.5% of the respondents picked community development association as the major stakeholder in the provision of road infrastructure, 2.9% picked self-help project while 0.2% of the respondents said well spirited individuals are stakeholders in the provision of road infrastructure. In Ila local government area, 87.1% of the respondents said the major stakeholder in the provision of road infrastructure are the government, 10.9% said community development associations are the stakeholders while 1.9% of the respondents are of the opinion that self-help projects are the stakeholders in the provision of road infrastructure in the area.

Table 4: Provision of Road Network

| Local Gov't | Government | Community Development Association | Well spirited individuals | Self-help project | Total |
|--------------------|-------------------|--|----------------------------------|--------------------------|--------------|
| Bouwaduro | 140 (90.9%) | 12 (7.7%) | 0 (0.0%) | 2 (1.3%) | 154 (100%) |
| Ifedayo | 566 (93.4%) | 21 (3.5%) | 1 (0.2%) | 18 (2.9%) | 606 (100%) |
| Ila | 576 (87.1%) | 72 (10.9%) | 0 (0.0%) | 13 (1.9%) | 661 (100%) |
| Total | 1282 (90.2%) | 105 (7.2%) | 1 (0.1%) | 33 (2.3%) | 1422 (100%) |

Source: Fieldwork, 2013

On the provision of drainage facilities across Ila federal constituency, table 5 reveals that 99.6% respondents in the study area which comprises Boluwaduro, Ifedayo, and Ila Local Government see that construction of drainage was done by governments. The drainage channel project at the side of the rural roads in order to stop erosion of road shoulder was done by the local governments by either the chairman or councilor to serve as constituent project. 0.2% respondents sees Community Development Association to be part of stakeholder that can also engage in construction of drainage through the community effort while 0.1% and 0.1% respondents see well spirited individual and self-help project respectively also role to play in this area.

Table 5: Provision of Drainage

| Local Gov't | Government | Community Development Association | Well spirited individuals | Self-help project | Total |
|--------------------|-------------------|--|----------------------------------|--------------------------|--------------|
| Bouwaduro | 154 (100%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 154 (100%) |
| Ifedayo | 602 (99.2%) | 3 (0.5%) | 1 (0.2%) | 1 (0.2%) | 607 (100%) |
| Ila | 661 (100%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 661 (100%) |
| Total | 1417 (99.6%) | 3 (0.2%) | 1 (0.1%) | 1 (0.1%) | 1422 (100%) |

Source: Fieldwork, 2023

In addition, on the maintenance and grading of roads across the study area, table 6 reveals that 99.5% respondents show the constant grading of road to make it motorable all the season was the sole responsibility of government. The highest percentage of respondents from the table indicate that government is the major body responsible for the grading and maintenance of rural roads while 0.4% and 0.1% respondents see Community Development Association and Well spirited individuals are less responsible for grading the roads.

Table 6: Grading/Road Maintenance

| Local Gov't | Government | Community Development Association | Well spirited individuals | Total |
|-------------|--------------|-----------------------------------|---------------------------|-------------|
| Bouwaduro | 154 (100%) | 0 (0.0%) | 0 (0.0%) | 154 (100%) |
| Ifedayo | 601 (99.0%) | 5 (0.8%) | 1 (0.2%) | 607 (100%) |
| Ila | 661 (100%) | 0 (0.0%) | 0 (0.0%) | 661 (100%) |
| Total | 1416 (99.5%) | 5 (0.4%) | 1 (0.1%) | 1422 (100%) |

Source: Fieldwork, 2023

Water Supply

One of the foremost needs of man for his daily survival is water. Realizing man's need for water, governments over the years have created one agency or the other to ensure adequate supply of water to the people. The agencies include several state water boards and corporations. Past water supply from public taps was free. According to Nubi (2002), government's inability to sustain the free lunch led to commercialization of water cooperation, thus restricting water supply to people that could afford it at the commercial rate. Consumers who cannot afford the commercial rate have their supplies cut off. Irregular electric power supply has often been blamed by the water cooperation for irregular water supply. Today, in most of the rural areas, the major source of water is hand dug well and Borehole provided by the government agency called Rural Water and Environmental Sanitation Agency (RUWESA) and European Union (EU) respectively. Presented in table 7 is the result of the findings from the study area on the stakeholders involved in the provision of portable water in Ila federal constituency. 99.2% of the respondents identify government as the major stakeholder in the provision of portable water in the area, while 0.7% and 0.1% identify community development association and well spirited individuals respectively as the actors in the provision of portable water in the study area. However, RUWESA and UNICEF are consulted in respect of portable water projects in the study area, where they agreed that hand-pump well and solar motorized pump are to be provided in the three local government areas that made Ila Federal Constituency. This made them one of the actors in the provision of portable water supply in Ila federal constituency.

Table 7: Provision of Portable water

| Local Gov't | Government | Community Development Association | Well spirited individuals | Total |
|-------------|--------------|-----------------------------------|---------------------------|-------------|
| Bouwaduro | 154 (100%) | 0 (0.0%) | 0 (0.0%) | 154 (100%) |
| Ifedayo | 596 (98.2%) | 0 (1.6%) | 1 (0.2%) | 607 (100%) |
| Ila | 661 (100%) | 0 (0.0%) | 0 (0.0%) | 661 (100%) |
| Total | 1411 (99.2%) | 10 (0.7%) | 1 (0.1%) | 1422 (100%) |

Source: Fieldwork, 2023

Electricity Supply

Nationally, the supply of electricity has been the sole responsibility of the Ibadan Electricity Development Centre (IBDEC) for the South West. Regular supply of electricity is very necessary for the all – round development of any nation. Aside domestic uses, commercial and industrial concerns need constant supply of electricity for their businesses. However, our electricity supply is characterized by frequent power cuts. Sometimes some rural communities in the study area remain without electric power supply

for hours, weeks and even months (Iseh, 2003). Owing to the “epileptic” electricity supply, many consumers have resorted to using alternatives such as Solar light and Generators. The irregular supply of electricity has caused many people using electricity for their daily activities like Welders, Traders using electricity for refrigerator, Cold room and those operating cottage industries will produce below capacities and in some extreme cases, fold up, thereby forcing many employees into the labor market (Uchendu, 2007). Respondents in Ila federal constituency were asked who the major stakeholder in the provision of electricity is and the responses are presented in table 5.8. Majority of the respondents across the three local government area that made up Ila federal constituency identified that the government is the major stakeholder in the provision of electricity supply, 3.4% of the respondents identify community development association as the stakeholder in the provision of electricity supply, 1.6% identify with well spirited individuals as the stakeholder in the provision of electricity supply while 1.4% of the respondents identified with the self-help projects as the stakeholder in the provision of electricity supply in the study area.

Table 8: Major Stakeholders in the provision of electricity supply

| Local Gov't | Government | Community Development Association | Well spirited individuals | Self-help project | Total |
|-------------|--------------|-----------------------------------|---------------------------|-------------------|------------|
| Bouwaduro | 74 (77.08%) | 15 (15.7%) | 5 (5.2%) | 2 (2.8%) | 96 (100%) |
| Ifedayo | 93 (87.06%) | 02 (1.8%) | 7 (6.2%) | 5 (4.4%) | 113 (100%) |
| Ila | 641 (96.09%) | 13 (1.9%) | 2 (0.3%) | 5 (0.8%) | 661 (100%) |
| Total | 814 (93.06%) | 30 (3.4%) | 14 (1.6%) | 12 (1.4%) | 870 (100%) |

Source: Fieldwork, 2023

Responses were also gotten on the stakeholders involved with the responsibility of providing and installation of electrical poles and cables across the study area. The findings are presented in table 5.9 where 93.6% of the respondents picked the government as the major stakeholder responsible with the provision and installations of electrical poles and cables, 2.9% of the respondents believe it is the community development associations that are responsible for the installation electrical poles and cables, 2.1% and 1.4% of the respondents identified it to be well spirited individuals and self-help projects respectively.

Table 9: Installation of Electrical Poles and Cables

| Local Gov't | Government | Community Development Association | Well spirited individuals | Self-help project | Total |
|-------------|--------------|-----------------------------------|---------------------------|-------------------|------------|
| Bouwaduro | 74 (77.01%) | 13 (13.5%) | 7 (7.3%) | 2 (2.1%) | 96 (100%) |
| Ifedayo | 99 (87.06%) | 02 (1.8%) | 8 (7.1%) | 4 (3.5%) | 113 (100%) |
| Ila | 641 (96.09%) | 11 (1.7%) | 3 (0.5%) | 6 (0.9%) | 661 (100%) |
| Total | 814 (93.6%) | 26 (2.9%) | 18 (2.1%) | 12 (1.4%) | 870 (100%) |

Source: Fieldwork, 2023

The Program of the Directorate

The post fourth plan period witnessed the establishment of the Directorates of Food, Roads and Rural Infrastructure (DFRRI) in 1985 for the purpose of providing rural infrastructures in the countryside. The law establish the Directorates was promulgated under Decree number four 1987. The core of the Directorates program is the promotion of productive activities, besides; the directorate recognizes the provision of rural infrastructures such as feeder roads, water, electricity and housing as essential for the enhancement of the quality of life in the rural areas.

In pursuit of its objectives, DFRRI also planned to co-operate with organizations like Nigeria Building and Road Research Institute (NBRRI) as well as Rural Water and Environmental Sanitation Agency (RUWESA) and The Directorate of Food, Roads and Rural Infrastructure (DFRRI) does not get involved in direct implementation of the program. Rather, for the purposes of the program implementation, the directorate uses as its main agents, the state and the local government to execute its programs. The funds for the programs of the Directorate are made available directly to each state government who then goes to the disbursement of such fund to the local government. The Local Government in the federation is constituted into rural development committees. These committees embrace the local government officials and the rural communities.

Overall, about 433 million naira was allocated to the directorates in 1986 for the purpose of implementing its programs. But only 300 million naira was actually disbursed. In 1987 and 1988, 500 million naira and one billion naira respectively were allocated to the directorates. Within the few years of DFRRI existence some notable achievements were made. For instance, between 1986 and 1988 about 30,000 kilometers of rural roads have been constructed. Although, it could be argued that length of road constructed were just 50% short of government target of 60,000km for 1968, yet the directorate should be commended for opening up the rural areas within a short period of time. The Directorates made rural road development as its first priority because of the belief that unless there is access to rural communities, all other infrastructures such as electricity, water and farm inputs cannot reach the rural people.

CONCLUSION

This study examined the distribution pattern of selected infrastructure in Ila federal constituency of Osun state, Nigeria. Considering the need to ensure user-dwellings in our cities, housing researchers and planners of the built environment must make relevant inputs that would form the basis for rationally explaining and achieving qualitative housing. One such input is to generate relevant data on specific spatial-interactive behavior and attitude of households. What must be considered in this regard is the relevance of design approaches to the particular culture in question, which should include, among other issues, user acceptability of dwellings, satisfaction of habits and life- styles in terms of functionalism, and the adaptability to changes. Further research effort is therefore required along this direction to gain a comprehensive and more realistic approach to the housing requirement. The policy implications of this study's finding suggest that while urban residents should have access to a suitable house- type that fulfills their housing needs and aspirations, the quality of urban housing, and by extension, the quality of life for urban residents, can be enhanced if urgent attention is paid by government to the provision of basic social amenities and infrastructural facilities. To upgrade the quality of the existing urban housing stock, adequate awareness should be created among residents regarding the need for housing improvement. Financial resources should be provided by the granting of interest-free soft loans to low-income households to encourage them to improve the wellings in affected areas.

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