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ASSESSMENT AND PREDICTION MODEL FOR COMMUNITY RESILIENCE IN CHINA BASED ON GANS AND RANDOM FOREST REGRESSION

**Quan Wen¹, Mazran Ismail², Muhammad Hafeez Abdul Nasir³,
Jing Zhao⁴, Zhang Jing⁵**

*^{1,2,3,4,5} School of Housing, Building and Planning,
UNIVERSITI SAINS MALAYSIA*

Abstract

Community resilience is a vital aspect of urban planning and disaster management, especially in rapidly urbanizing countries like China, where frequent natural disasters pose significant threats. This study addresses the challenge of assessing and predicting community resilience in China by developing an innovative model using Generative Adversarial Networks (GANs) and Random Forest Regression. The model specifically tackles issues of data insufficiency and prediction inaccuracy in traditional methods. The study surveyed 33 diverse communities across various regions in China and generated 300 additional virtual samples using GANs to enhance model robustness. The model incorporates the Analytic Hierarchy Process (AHP) to ensure scientific accuracy in determining indicator weights. Results indicate a substantial improvement in predictive performance, with a Mean Squared Error (MSE) of 0.00055 and a coefficient of determination (R^2) of 0.99578. This study contributes a novel framework for evaluating community resilience, providing a scientific foundation for disaster prevention and mitigation strategies in urban governance.

Keywords: Community Resilience, GANs, Random Forest Regression, Urbanization, Disaster Prevention

² Corresponding author. Email: mazran@usm.my

INTRODUCTION

Research Background

As global climate change intensifies and natural disasters become more frequent, community resilience has emerged as a crucial research topic in urban planning and public administration. As the most populous country in the world, China's assessment of community resilience is of paramount importance for safeguarding the lives and property of its residents and enhancing the overall level of urban governance (Zhao et al., 2023). In recent years, the acceleration of urbanization has increasingly exacerbated the risks and challenges faced by communities (Hu et al., 2023). Natural disasters such as earthquakes, floods, and typhoons occur frequently, posing significant threats to the lives and properties of community residents (Ma et al., 2021). Concurrently, the socioeconomic structure of communities is continuously evolving, with issues such as population aging and the increase in migrant populations imposing higher demands on community resilience (Ma et al., 2021). Therefore, constructing a scientifically sound community resilience assessment model to promptly identify and address vulnerabilities in communities facing disasters and to enhance comprehensive disaster prevention and mitigation capabilities holds significant practical importance (Suleimany et al., 2022).

Research Objectives

The primary objective of this study is to develop a Chinese community resilience assessment and prediction model based on Generative Adversarial Networks (GANs) and Random Forest Regression. This model aims to address issues of data insufficiency and prediction inaccuracy present in traditional assessment methods. Specific objectives include extracting key indicators affecting community resilience to construct a systematic assessment framework, using the Analytic Hierarchy Process (AHP) to determine the weights of these indicators to ensure scientific accuracy in the assessment results, and employing GANs to generate additional virtual samples for quantitative assessment and prediction of community resilience using Random Forest Regression.

Research Innovations and Significance

This study demonstrates innovation in several key areas. The introduction of Generative Adversarial Networks (GANs) facilitates the creation of numerous virtual samples, addressing the issue of inaccurate evaluation results caused by insufficient data in traditional methods. GANs enhance model generalization by generating new samples that are consistent with the characteristics of actual data. Utilizing the random forest regression algorithm enables the quantitative assessment and prediction of community resilience. Random forest regression is effective in handling high-dimensional data and possesses strong noise resistance,

thereby improving the accuracy and stability of the model's predictions. Additionally, a comprehensive community resilience assessment indicator system is developed through literature review and expert discussions. This system encompasses both tangible resources and infrastructure, as well as soft indicators such as social relationships and information dissemination, providing a holistic view of community resilience. These innovations offer novel methods and tools for evaluating community resilience and provide a scientific basis for the formulation and implementation of disaster prevention and mitigation policies, thus holding significant theoretical and practical value.

LITERATURE REVIEW

Community Resilience

Research on community resilience began in the late 20th century and has become an important field of study with the increasing focus on climate change and disaster management (Xu et al., 2021). Community resilience is generally defined as the capacity of a community to respond to, adapt to, and recover from disasters. Early studies primarily concentrated on defining the concept and constructing theoretical frameworks for community resilience (Ma et al., 2021). As research progressed, scholars increasingly focused on evaluating community resilience through quantitative indicators (Zhao et al., 2023). The importance of these assessments lies in their ability to inform strategies that safeguard lives and property, enhance urban governance, and address the challenges of rapid urbanization, which are critical in disaster-prone regions.

Internationally, significant progress has been made in community resilience assessment (Suleimany et al., 2022). For instance, the United States National Academy of Sciences proposed a community resilience assessment framework based on social, economic, institutional, and environmental dimensions (Mieler et al., 2015). Similarly, the Australian Disaster Resilience Institute identified seven dimensions for assessing community resilience, including social capital, community competence, and information and communication (Dinh & Pearson, 2015). These studies provide an essential theoretical foundation and reference for this research.

In China, research on community resilience assessment started relatively late but has developed rapidly (Guo et al., 2020). Chinese scholars have proposed community resilience assessment models tailored to the Chinese context (Ntontis et al., 2020). For example, some scholars have developed indicator systems for community resilience assessment, focusing on disaster prevention and mitigation capabilities, social support networks, and economic recovery abilities (Xu et al., 2021). Others have introduced methods based on multivariate statistical analysis and fuzzy comprehensive evaluation. These studies offer valuable insights for this research. These efforts are crucial in

enhancing the resilience of communities, thereby supporting urban governance and ensuring the safety and well-being of the population amid the pressures of rapid urbanization.

RESEARCH METHODOLOGY

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a method that decomposes complex decision-making problems into a hierarchical structure, allowing for layer-by-layer analysis and comparison to determine the relative importance of various factors (Wang et al., 2020). In this study, key indicators influencing community resilience are identified through literature review and expert interviews (Pilevar et al., 2020). The experts selected for the interviews were professionals with extensive experience in urban planning, disaster management, and public policy, chosen based on their academic qualifications and practical expertise in these fields. An interview guideline was developed to ensure consistency, focusing on collecting data related to the significance of various resilience indicators. Subsequently, multiple experts are invited to conduct pairwise comparisons of these indicators, constructing a judgment matrix. The judgment matrix was developed by systematically comparing each pair of indicators, with experts providing their assessments based on the data collected during the interviews. AHP is then used to calculate the weights of each indicator, ensuring the scientific validity and accuracy of the assessment results (Lyu et al., 2020).

Generative Adversarial Networks (GANs)

Generative Adversarial Networks (GANs) are deep learning models that generate new data through adversarial training (Jeong et al., 2022). In this study, GANs are utilized to generate a large number of virtual community samples, addressing the insufficiency of actual survey data. The specific method involves first collecting basic data from real communities, which refers to the selected 33 diverse communities across China, encompassing urban, suburban, and rural areas to train the generator and discriminator (Shoshan et al., 2021). These communities were chosen to provide a comprehensive representation of different socio-economic conditions, infrastructure levels, and disaster risks. This training enables the generator to produce new samples that resemble the actual data distribution (Mescheder et al., 2018). Through repeated training, meaning multiple cycles of adjusting the generator and discriminator based on feedback, through repeated training, the generated virtual samples effectively enhance the model's generalization capability and predictive accuracy (Wiese et al., 2020).

Random Forest Regression

Random Forest Regression is an ensemble learning algorithm based on multiple decision trees (Kumar et al., 2020). In this study, the random forest regression algorithm is employed for the quantitative assessment and prediction of community resilience (Lyu et al., 2020). The specific method involves combining actual survey data, which refers to the data collected from the 33 diverse communities across China, including detailed demographic, socio-economic, and resilience-related information, with virtual samples generated by GANs to construct training and testing sets (Irfan et al., 2022). The random forest model is then trained and used to predict community resilience. The effectiveness of the model in practical applications is evaluated through cross-validation (Pilevar et al., 2020).

RESULTS AND ANALYSIS

Framework Derived from Literature Review and Expert Discussions

The community resilience assessment framework presented in Figure 1 is derived from extensive literature review and expert discussions conducted by the research team. To ensure the scientific rigor of the framework, the team reviewed a substantial number of studies on community resilience assessment, drawing on frameworks proposed by authoritative institutions such as the United States National Academy of Sciences and the Australian Disaster Resilience Institute. Additionally, several experts in community development and disaster management were consulted for in-depth discussions and feedback. This multi-layered and multi-faceted research approach ensures the framework's theoretical and practical reliability and feasibility.

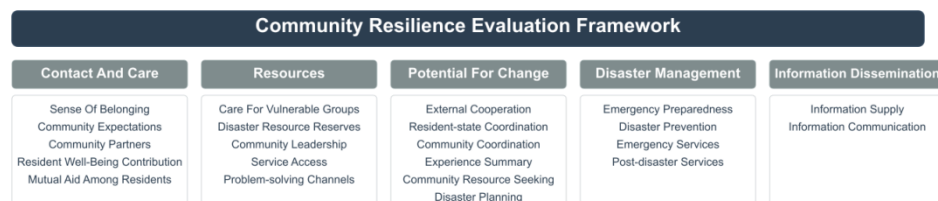


Figure 1: Community Resilience Evaluation Framework (Author's Creation)

The assessment framework in Figure 1 includes five primary dimensions: connectivity and care, resources, adaptive capacity, disaster management, and information dissemination. These dimensions and their specific indicators were selected based on an extensive review of the literature and expert consultations, ensuring that they reflect the most critical aspects of community resilience as identified in previous studies. Each dimension encompasses several

specific indicators, such as sense of belonging, community expectations, emergency preparedness, and information exchange. These indicators were chosen for their relevance and proven impact on community resilience in the context of disaster management, as highlighted in prior research. Evaluating these elements provides a comprehensive understanding of a community's overall capability to respond to disasters and emergencies, thereby offering a scientific basis for the formulation and implementation of community disaster prevention and mitigation policies. This framework is informed by key insights from the literature, particularly regarding the importance of both tangible and intangible resources in enhancing community resilience.

Weight Calculation Using Analytic Hierarchy Process (AHP)

Table 1: Demographic Information of Participating Experts (Author's Creation)

Expert Code	Gender	Title	Research Field
Expert A	Male	Lecturer	urban and rural planning
Expert B	Male	Lecturer	urban and rural planning
Expert C	Male	Senior Designer	Architecture
Expert D	Male	Lecturer	Architecture
Expert E	Male	Lecturer	urban and rural planning
Expert F	Female	Senior Engineer	Disaster
Expert G	Female	Associate Professor	Disaster
Expert H	Male	Associate Professor	Government management

The weight results calculated using the Analytic Hierarchy Process (AHP) are derived from the systematic analysis and pairwise comparisons conducted by eight experts from fields such as community development, disaster management, and public policy. As shown in Table 1, these experts, leveraging their extensive professional knowledge and practical experience, conducted detailed comparisons and weight evaluations of various community resilience assessment indicators. To ensure the scientific validity and accuracy of the results, the experts adopted a rigorous set of criteria, including the scope of impact, importance, and performance of each indicator in different contexts.

Table 2: Weighted Indicators for Assessing Community Resilience (Author's Creation)

Indicator	Weight
Emergency Preparedness	0. 1999
Emergency Services	0. 0942
Disaster Resource Reserve	0. 0916
Disaster Prevention	0. 0666
Community Leadership	0. 0591
Sense of Belonging	0. 0568
Post-disaster Services	0. 0471
Service Access	0. 0459
Information Communication	0. 0426
Care for Vulnerable Groups	0. 0373
Resident Well-being Contribution	0. 0373
Disaster Planning	0. 0365
External Cooperation	0. 0262
Problem-solving Channels	0. 0205
Community Resource Seeking	0. 0201
Community Expectations	0. 0197
Community Fairness	0. 0194
Mutual Aid among Residents	0. 0185
Information Supply	0. 0179
Resident-Leader Communication	0. 0143
Community Collaboration	0. 0122
Community Trust	0. 0113
Experience Summary	0. 0049

Specifically, Table 2 illustrates emergency preparedness holds the highest weight at 0. 1999, indicating that disaster and emergency-related preparations are considered the most critical factor in community resilience. Following closely are emergency services and disaster resource reserve, with weights of 0. 0942 and 0. 0916, respectively. This underscores the significance of the availability of emergency services and disaster resources in enhancing community resilience during disasters. Additionally, indicators such as community leadership, sense of belonging, post-disaster services, and access to services also have substantial weights, highlighting the importance of community management, social cohesion, and service assurance in improving community resilience. Conversely, softer indicators such as community collaboration, community trust, and experiential learning have relatively lower weights but remain essential components of community resilience. These weight results

provide crucial reference points for communities in formulating disaster prevention and mitigation strategies and enhancing resilience.

Scoring Communities

To develop the predictive model, the research team selected 33 communities from the capital of China, provincial capitals, typical cities, towns, and rural areas as study samples. These communities were chosen based on specific selection criteria, including their geographic location, population density, socio-economic diversity, and historical exposure to natural disasters. The selection criteria were based on several considerations. First, the sample ensured broad geographic representation to reflect the differences and commonalities in community resilience across China. Second, it included communities of varying sizes and structures, from densely populated urban communities to relatively dispersed rural communities, to comprehensively understand how different types of communities respond to disasters. Finally, communities with different levels of disaster risk were chosen to capture the diversity of community resilience in facing various natural disasters such as earthquakes, floods, and typhoons. This diverse selection aimed to ensure that the model could generalize well across different community contexts and provide robust insights into resilience strategies.

During data collection, the research team conducted field surveys to gather detailed data from these 33 communities. The surveys were completed by community members, local officials, and representatives from relevant agencies, with a total of approximately 500 respondents participating across all communities. After completing the surveys, eight experts from fields such as community planning, disaster management, and public policy were invited to score the community data. These experts used the indicator weights previously determined through the Analytic Hierarchy Process (AHP) to comprehensively score each community, resulting in a total score for each community. The scores in Figure 2 reflect the varying levels of community resilience, with higher scores indicating stronger resilience. For example, Provincial Capital Community 4 achieved the highest score of 4.1235, signifying robust resilience, likely due to well-developed infrastructure and effective disaster management systems. In contrast, Rural Community 2 received the lowest score of 1.5755, highlighting vulnerabilities possibly related to limited resources and weaker infrastructure. This approach not only allowed the research team to assess the resilience levels of the communities but also provided a reliable data foundation for subsequent model training.

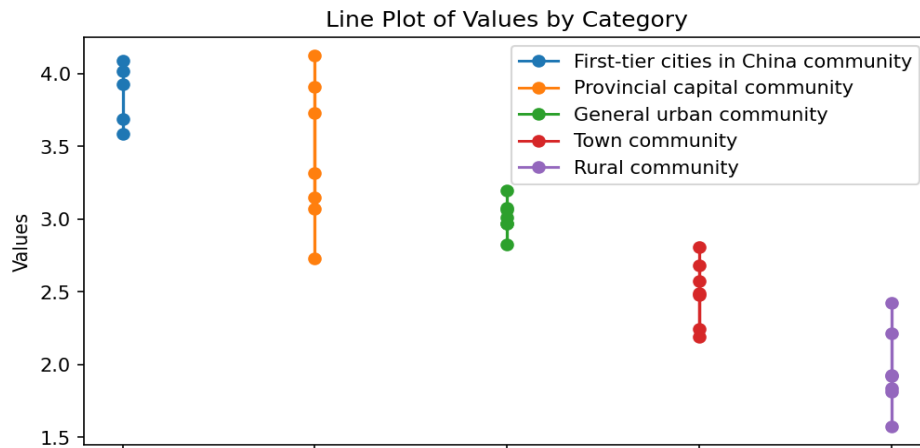


Figure 2: Community Resilience Scores by Community Type (Author's Creation)

Model Training and Results

The random forest regression algorithm was employed to train the model, with preliminary results indicating a Mean Squared Error (MSE) of 0.09 and a coefficient of determination (R^2) of 0.81. These results suggest that the model can explain a substantial portion of the data variance, though its interpretability and predictive accuracy are still limited. Specifically, an R^2 score of 0.81 indicates that while the model has a good fit, approximately 19% of the variance remains unexplained.

The primary reason for this limitation is the small sample size, with only 33 community samples, which restricts the model's generalization ability and predictive accuracy. Furthermore, the diversity and complexity of community data add to the challenges of model training, limiting the model's performance in capturing the intricate relationships among different dimensions of community resilience. However, the detailed analysis of these 33 diverse communities provides valuable insights into the key factors influencing community resilience, making the presented data a useful reference for future studies. While the model's generalizability may be limited, the methodological framework and findings can guide larger-scale studies and inform the development of more robust models as additional data becomes available. Therefore, increasing the sample size and enhancing data diversity will contribute to improving the model's interpretability and predictive accuracy (Dimitriadis et al., 2018).

To address the issue of insufficient community sample size, this study incorporated Generative Adversarial Networks (GANs) for deep learning (Joshi et al., 2022). By training on the original data from 33 communities, GANs successfully generated 300 virtual samples. Through the adversarial training of the generator and discriminator, GANs produced virtual samples that closely matched the feature distribution of the actual data, effectively mitigating the

problem of limited sample size. These virtual samples are considered representative of real-world conditions because GANs are designed to replicate the feature distribution of actual data. Through the adversarial training of the generator and discriminator, GANs produced virtual samples that closely matched the characteristics and variability observed in the real communities. This process ensures that the virtual samples reflect the diversity and complexity of the real-world environments, effectively mitigating the problem of limited sample size and enhancing the robustness of the model's predictions.

These virtual samples not only increased the quantity of training data but also enhanced the model's generalization capability and predictive accuracy (Salimans et al., 2016). Consequently, they provided a robust data foundation for subsequent training of the random forest regression model, significantly improving its performance in assessing community resilience.

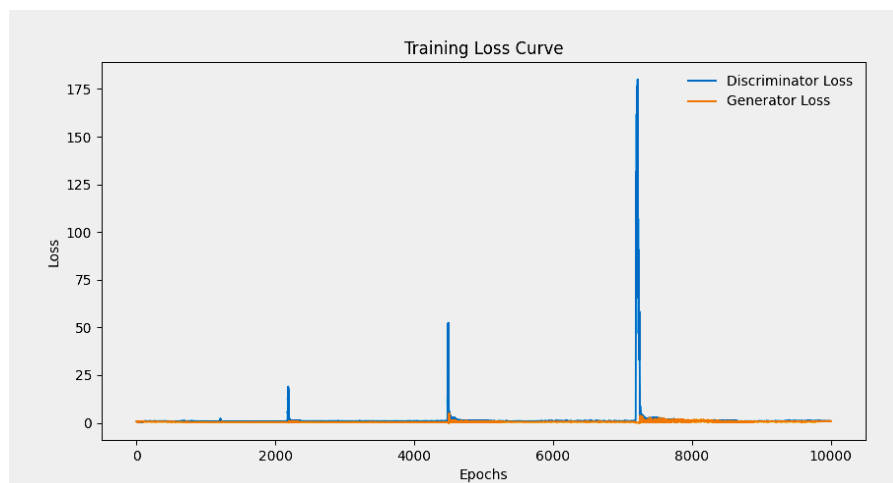


Figure 3: Training Loss Curve for GAN Model (Author's Creation)

The training loss curve in Figure 3 illustrates the changes in generator loss and discriminator loss during GANs training (Pan et al., 2020). The X-axis represents the number of epochs, while the Y-axis represents the loss values. The figure shows that the discriminator loss (blue curve) experiences some noticeable fluctuations in the early stages of training but generally stabilizes over time. In contrast, the generator loss (orange curve) remains relatively stable throughout the training process. This indicates that as training progresses, the generator and discriminator gradually reach a dynamic balance, with the generator producing realistic samples and the discriminator effectively distinguishing between real and generated samples. These training results demonstrate that the GANs model successfully generated virtual community data with realistic features, thereby

enhancing the training effectiveness and predictive accuracy of the subsequent model.

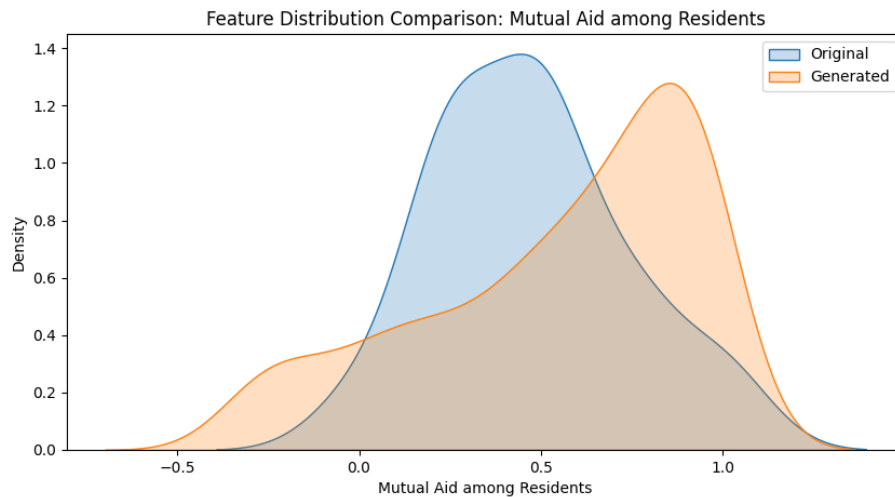


Figure 4: Feature Distribution Comparison for 'Mutual Aid among Residents' (Author's Creation)

As shown in Figure 4, the feature distribution comparison plot in the figure illustrates the distribution of the "Mutual Assistance among Residents" indicator in both the original sample data and the virtual sample data generated by GANs. The X-axis represents the values of "Mutual Assistance among Residents," and the Y-axis represents density. The blue curve represents the distribution of the original data, while the orange curve represents the distribution of the generated data. It can be observed that the distribution of the generated data closely aligns with the overall shape of the original data distribution, indicating that GANs successfully generated virtual samples with characteristics similar to the actual data.

This consistency validates the reasonableness and authenticity of the feature distribution in the GANs-generated virtual samples, thereby enhancing the data foundation for subsequent model training (Pan et al., 2020). Introducing these virtual samples enables the model to better understand the complex relationships within community resilience, providing more accurate assessment and prediction results in practical applications. This outcome demonstrates the effectiveness of using GANs technology to generate data, offering a feasible solution to the problem of insufficient actual data and providing a solid foundation for constructing community resilience assessment models.

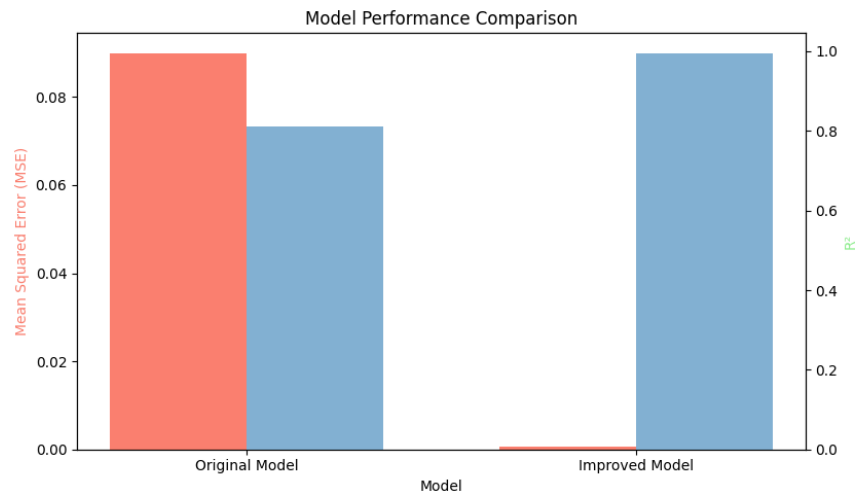


Figure 5: Model Performance Comparison (Author's Creation)

Combining the 300 virtual samples generated by GANs with the original 33 community data samples, the random forest algorithm was used for model training. The final results shown in Figure 5 illustrates that the Mean Squared Error (MSE) significantly decreased to 0. 00055, and the coefficient of determination (R^2) increased to 0. 99578. This indicates that the use of GANs-generated virtual samples substantially improved the model's predictive accuracy and explanatory power, allowing the model to more accurately reflect the actual conditions in community resilience assessment. This result proves the effectiveness and feasibility of GANs in enhancing datasets and improving model performance.

CONCLUSION

This study aims to address the issues of insufficient data and inaccurate predictions in traditional methods by constructing a community resilience assessment and prediction model based on Generative Adversarial Networks (GANs) and random forest regression. In the context of China, the world's most populous country, evaluating community resilience is crucial for safeguarding residents' lives and property and enhancing urban governance. As urbanization accelerates, communities face increasing risks and challenges, including frequent natural disasters and changes in socio-economic structures, making the development of a scientific and reasonable community resilience assessment model imperative.

The innovation of this study lies in the use of GANs to generate a large number of virtual samples, combined with the random forest regression algorithm for quantitative assessment and prediction of community resilience. The evaluation

indicator weights determined by the Analytic Hierarchy Process (AHP) ensure the model's scientific validity and accuracy. The research results indicate that models using all features for evaluation performed poorly on the test set, whereas the inclusion of GANs-generated virtual samples significantly improved the model's predictive accuracy and generalization capability. Specifically, the model with GANs-generated samples achieved a Mean Squared Error (MSE) of 0.00054 and a coefficient of determination (R^2) of 0.99578, demonstrating high explanatory power and predictive accuracy.

The findings of this study are directly relevant to the 33 communities analyzed, as they provide a data-driven foundation for enhancing disaster preparedness and resilience at the local level. By improving the accuracy of resilience assessments, the model contributes to safeguarding lives and property in these communities, helping local authorities to make informed decisions on resource allocation and disaster mitigation strategies. Furthermore, the model supports urban governance by offering a tool that can be adapted to other rapidly urbanizing regions, thereby addressing the broader challenges of urbanization and increasing disaster risk.

The findings show that GANs technology has significant advantages in generating virtual samples and enhancing datasets, effectively addressing the issue of insufficient data. When combined with the random forest regression algorithm, the model excels in handling high-dimensional data and noise resistance, significantly improving the predictive accuracy and interpretability of community resilience assessments. This method not only provides a better understanding of the complex relationships within community resilience but also offers more accurate assessment and prediction results in practical applications. Future research should aim to further expand the sample size and increase data diversity to enhance the model's generalization capability and predictive accuracy. Additionally, exploring other deep learning algorithms and ensemble learning methods could help develop more precise and robust community resilience assessment models. Collaboration with experts in related fields to optimize and refine the evaluation indicator system will ensure the model's operability and effectiveness in practical applications. This study provides new methods and tools for community resilience assessment, offering a scientific basis for the formulation and implementation of disaster prevention and mitigation policies, and holds significant theoretical and practical value.

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