

Research on Rural Design of Industrial Towns on the Urban Fringe Based on the Needs of China's National Spatial Planning System

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Abstract: As urbanization continues, villages and industrial townships in peri-urban areas are facing increasingly complex challenges and opportunities. These areas are usually at the crossroads of urban and rural areas, and are rich in resources and potential, but are also accompanied by environmental, economic and social problems. In May 2019, China formally promulgated the Several Opinions of the State Council of the Central Committee of the Communist Party of China on the Establishment and Supervision of the Implementation of a Territorial Spatial Planning System (hereinafter referred to as the Several Opinions), which defined the overall framework of the territorial spatial planning system of five levels, three categories, and four systems, laying the foundation for the top-level design of the territorial spatial planning system [1]. In January and September 2020, the General Office of the Ministry of Natural Resources of China issued the "Guidelines for the Preparation of Provincial Territorial Spatial Planning (Trial)" and "Guidelines for the Preparation of Municipal Territorial Spatial Master Plans (Trial)", which provide guidelines for the preparation and implementation of territorial spatial master plans at all levels of the provinces, municipalities, townships, and townships [2]. In this paper, the author takes Houfu Village, Qingkou Town, Minhou County, Fujian Province, China, as an example, comprehensively analyzes the existing advantageous resources of Houfu Village, combs through the development trend of existing Urban Marginal Townships in China, and then draws on the experiences of domestic and international excellent cases. Its purpose is to explore the rural planning system of Urban Marginal Townships in the light of the new requirements of the national land spatial planning system, and to solve the regional needs to meet the high-quality development of the village economy and the high quality of life of the village residents. This paper has a certain reference for the design and planning of the same type of townships and villages.

Keywords: Urban fringe industrial townships¹; rural design²; urban spatial planning³

Author summary

The manuscript titled "Research on Rural Design of Industrial Towns on the Urban Fringe Based on the Needs of China's National Spatial Planning System" explores the challenges and strategies for rural design in urban fringe industrial townships within the context of China's territorial spatial planning. It highlights the importance of balancing urbanization with rural revitalization by addressing ecological, economic, and cultural considerations.

The author examines the case of Houfu Village in Fujian Province, analyzing its resources and the impact of China's urban-rural development policies. The study draws on domestic and international examples to propose strategies that enhance sustainable development, cultural preservation, community participation, and agricultural diversification.

The research methods include the Fuzzy Delphi and Fuzzy Hierarchical Analysis methods to systematically identify and prioritize the key elements of rural planning. The

findings emphasize the importance of ecological conservation, stakeholder engagement, and industrial development tailored to the unique needs of urban fringe areas.

The manuscript contributes to the ongoing discourse on urban-rural integration, offering insights that are relevant for policymakers and planners engaged in similar contexts.

1. Introduction

The rural design on urban fringe industrial townships intends to address the challenges between urbanization and rural development. De Toro and Fierro used the transversality of the concept of sustainability as a basis for assessing the spatial sustainability assessment model (SSAM) through the combination of geographic information systems (GIS) and multi-criteria analysis in order to assess the sustainable development of urban fringe areas achieved sustainable interactions between built and natural environments in urban fringe-type areas by considering socio-economic factors and ecological principles [3]. Scholars such as Tzortzi, Guaita investigated the role of green infrastructures and nature-based solutions in redefining urban fringe-type areas, in particular through the preservation and use of cultural heritage to enhance the urban fringe's environmental and socio-cultural quality of the fringe area [4]. In addition, scholars such as de Luca, López-Murcia and others present the European approach to regenerate rural areas through heritage-led programs, emphasizing the importance of community participation and broad stakeholder involvement in the rural regeneration process. Perrin, Clément and others review the policies of developed countries to protect farmland on the urban fringe, with a focus on the Mediterranean region. By analyzing the issues related to farmland protection, the article emphasizes the need for more sustainable land management policies that focus on the specific needs of agricultural systems [5]. The study by Vicente-Vicente, Sanz-Sanz, and other scholars proposes a new methodology for assessing regional food self-sufficiency, combining region-specific cropping patterns, soils, and topographic data, to explore the potential for urban fringes for agricultural diversification and food supply chains [6]. The above studies are synthesized and broadly categorized into four directions for discussion.

1.1 Literature review

This paper reviews research related to rural design in industrial townships on the urban fringe and discusses it in four general directions.

Sustainable urban fringe development: emphasizes the key role of sustainability principles in the design of urban fringe industrial townships and villages. These studies often focus on the balance between environmental protection, resource utilization, social equity and economic growth. For example, researchers often explore strategies to reduce carbon emissions, improve resource efficiency [7] and improve green space and nature conservation [8], as well as the potential for ecological impacts on villagers' lives. For example, whether there are contradictions in urban socio-ecological measures in small towns, and the importance of the human environment to the village environment, etc. [9].

Rural regeneration and cultural preservation: On the urban fringe, rural regeneration and cultural preservation have also been emphasized in developed countries. This includes the restoration of historical heritage buildings, the preservation of traditional crafts and rural culture, and the promotion of cultural tourism. These efforts help to enhance the attractiveness of the countryside, reshape its cultural values and improve the quality of life of its inhabitants [10].

Agricultural diversification and food industries: Some developed countries are concerned with promoting agricultural diversification and the development of food industries to achieve sustainable agriculture [11], in order to increase the economic resilience of the rural areas. This may include support for organic agriculture, agro-processing and innovation in rural enterprises [12].

Community participation and management: Developed countries emphasize the importance of community participation and effective management. Researchers focus on

how to build partnerships in marginal urban areas, including governments, residents, non-profit organizations and the private sector, to jointly promote sustainable development goals [13].

In summary, much of the current research in the field of rural design in Urban Marginal Townships focuses on sustainability, rural regeneration, agricultural diversification, community management and technological innovation. These studies have provided important policy recommendations and practical experiences for the development of marginal urban areas, helping to address the challenges of urbanization and promote sustainable development.

And China has been increasingly researching the field of rural design on Urban Marginal Townships to meet the challenges of urbanization and rural revitalization. Taking Shanghai as a case study, scholars Deng Xiaoxia and Zhang Xiao summarized the types, evolutionary paths, and evolutionary characteristics of rural settlements in marginal urban areas, and put forward suggestions for rural planning and new rural construction in Shanghai's marginal urban areas[14]. Taking Laoyu Village in Jinan City as an example, Fan Yong and Wang Linshen explored the planning strategy for the transformation and development of villages in urban fringe areas under the background of strict ecological constraints, and put forward the trinity of rural planning paths of "spatial planning-industrial upgrading-community building [15]. Based on the background of rural revitalization, Han Wei and Zhao Yifu reviewed the development of rural spatial governance in large urban fringe areas driven by socio-economic changes, and extracted five rural spatial governance models in large urban fringe areas [16]. Drawing on domestic and international experiences, Ye Lin, Xing Zhong, and Yan Wentao summarized green spatial planning strategies for urban fringe areas at the spatial planning level [17]. Qu Wei proposed a guiding framework for the sustainable development of urban fringe areas in the process of urbanization by discussing the characteristics and roles of large urban fringe areas [18]. Xing Zhong, Tang Xizi and other scholars used literature surveys, conceptual analyses, and relevant historical studies as a basis for sorting out relevant conservation studies on the ecological environment of urban fringes [19]. Chen Xue and Liao Hanwen conducted a comparative study between the Randstad region of the Netherlands and Beijing's marginal villages to explore new ideas for the development of rural industries in Beijing's urban fringe [20]. Shi Chunyu summarizes the experience and lessons learned from 40 years of marginal community governance in France, which brings new perspectives on the direction of community governance in China's urban fringe area [21] as. It can be seen from this that domestic research on planning and design of Urban Marginal Townships mainly focuses on Urban Marginal Township planning and spatial layout, sustainable development and ecological environmental protection, rural industrial upgrading and rural entrepreneurship, community management and so on.

Planning and spatial layout of industrial townships and villages on the edge of urban areas: Chinese research focuses on how to rationally plan villages and industrial zones on the edge of urban areas, which includes research on land-use planning, urban-rural integrated development, rural revitalization planning, etc., in order to realize the efficient use of resources and rational spatial layout [22].

Sustainable development and ecological environmental protection: the principle of sustainable development is an important part of the domestic design and planning of industrial townships and villages on the edge of the city that cannot be ignored, which mainly includes ecological environmental protection, resource management and green industrial development. Chinese scholars have discussed more about how to reduce pollution, improve water quality, promote circular economy and other strategies [23].

Rural industrial upgrading and rural entrepreneurship: Chinese scholars focus on how to promote rural industrial upgrading and entrepreneurship in marginalized industrial townships and villages. This includes supporting rural enterprises, developing specialty industries and promoting rural financial innovation [24].

Community management: Chinese research has the same concept as foreign studies in emphasizing the importance of community management to promote sustainable development in marginal urban areas. This includes research on rural land system reform, villagers' self-government, community communicty,etc [25].

Chinese research on rural design for marginalized industrial townships is becoming increasingly diverse, and these studies provide important references for policy makers and practitioners, helping to promote sustainable development and integrated governance in marginalized urban areas.

The concept of Urban Marginal Townships: In the context of China's urban-rural development, Urban Marginal Townships are considered to be "transitional zones" with characteristics of both urban and rural areas, and the core of the city has a certain degree of diffusion phenomenon to the marginalized areas, which mainly involves the diffusion of production data and factors [16], and is a gradual change zone between the urban and rural economies. It is a gradual change zone between urban and rural economy [26]. Urban Marginal Townships often become an important node for the flow of factors such as population, industry and capital, and their economic development and social changes are relatively fast. As urban industrial development gradually crosses the labor-intensive stage and industries start to be transported to the periphery, Urban Marginal Townships rely on the cost advantage to gradually develop rural industries, which changes their original production structure and labor force employment structure [16].The concept of Urban Marginal Township can be well explained by George S. Wehrwein's definition of Urban Marginal Township. He believed that with the city as the center of the circle, the city, the city relied on the development of transportation, gradually "invaded" the surrounding areas. The invasion included not only the industry but also the way of life. Therefore Urban Marginal Township is actually a potential extension of the city [27]. Nick Gallent proposed that urban development would be curbed by economic pressure in a certain period, making it dependent on a large amount of cheap land on the edge of the city, leading to the emergence of urban fringe town land types [28]. The above understanding shows that cheap land rent and the shift of the industrial economy are important elements of the characterization of urban fringe townships.

The concept of industrial townships and villages: Industrial townships and villages are typical phenomena in the suburbs of metropolis. They are characterized by industrial industries as the main production function [29]. Usually, the situation is as follows: there exists some scale of industrial land in the village or town, the industrial industry is an important job security, and the development level of the factory is positively correlated with the economic level of the township or township. China's industrial townships and villages are affected by the policy of urban integration, and in the process of development, they have gradually formed the "three concentrations", which include the concentration of industry in parks, the concentration of farmers in towns, and the concentration of farmland in large-scale, forming a development model integrating industrialization, urbanization and agricultural modernization [30]. Industrial townships and villages are dominated by two types of industries. The first type is the industry related or complementary to the village society, environment and economy, and the other type is the industry completely different from the village economic environment [31]. Generally, most of China's industrial towns and rural industries belong to the second category. Their industries are mainly industries that have spread or been introduced from surrounding cities, such as the textile industry, toy manufacturing industry, e-commerce, and automobile industry.

Therefore, the concept of Urban Marginal Townships and Villages can be summarized as: towns and villages located on the edge of the city, relying on the convenient transportation development and low land rent to attract urban economic expansion, thereby sharing urban industrial resources, and taking industrial development as the main economy of towns and villages.

- 1.2 Case studies of rural design in Urban Marginal Townships with industry
 - (1). Rural revitalization projects in China

The Chinese government has launched the "Rural Revitalization" project, which aims to improve the environment and living conditions in rural areas. Urban Marginal Townships and Villages are also included in the scope of the Rural Revitalization project. This project has achieved certain results by improving the living environment [32], upgrading rural tourism and cultural industries [33], and the development of rural industries [34].

On June 29, 2020, Qibu Town, Luoyuan County, Fuzhou City, Fujian Province, China, was listed as a pilot demonstration unit of Fujian Provincial Rural Governance; in March 2021, "Qibu" Town was selected as a list of "2020 Key Characteristic Townships of Fujian Province for Rural Revitalization" [35], which is an excellent case of rural revitalization in China. Starting from the sewage and garbage control, remediation of existing buildings, the creation of public space, the excavation and presentation of special features, the standardization of management order, and the creation of a joint community, the planning and design of Starting from the town is comprehensive in several aspects. First of all, the planning will improve the rural ecological environment and the living environment of the residents as the primary task, the construction of sewage supporting pipe network in the village, the centralized collection of sewage in the town, the collected sewage into the main pipeline, and then to the sewage treatment station for unified treatment. Sewage treatment has greatly enhanced the quality of the village water environment, while residents enjoy a cleaner, more hygienic living environment, improving the quality of life of residents. And put forward "where to create space? For whom to create space?" With the problem as a guide, with the use of old houses and streets and the transformation of unused or underutilized public buildings, we have created canteens for the elderly, children's spaces, women's spaces, youth spaces and industrial spaces, restored the cultural heritage of the Song Dynasty ancient bridges, and created waterfront parks and places for public leisure and deliberation. It has been revitalized into a center for the inheritance of cultural skills, with local teachers giving lectures on Chinese culture, folk skills, She ethnic customs, celebrity anecdotes and historical origins on weekends. At the same time, the cultural center has been renovated to create a public activity space for women, with courses such as paper cutting, flower arranging, hand weaving, singing and dancing offered to encourage women to participate in the co-construction and sharing of town culture.

Considering the employment needs of young people in the village, Qibu Township has built a space for youth entrepreneurship in combination with the environmental improvement of the township, and has taken the opportunity of environmental improvement to provide industrial space such as a street of special flavors and an agricultural products exhibition and marketing center, cooperating with famous brand merchants, developing innovative agricultural products, and operating a live broadcasting platform in cooperation with the local youth, so as to smooth out the path of marketing of agricultural and special products. The design of the public space in Qibu Town has taken into account the needs of many people and created a comfortable, high-quality and convenient space for the local community through meticulous design. Through reasonable planning based on the starting point of "find some, demolish some, borrow some", 58 new parking spaces were added in front of and behind houses and along the alleys, and a centralized parking area was set up in the cultural square. The concept of breaking the whole into parts was used to solve the parking and traffic congestion problems along the central block, eliminate safety hazards in a timely manner, improve the appearance of the main street, and create a business atmosphere.

The following points provide valuable insights and lessons for subsequent planning and design.

Insisting on ecological priority and green development: Whether it is the case of Luoyuan County, which is mentioned in this paper, many successful cases of rural revitalization in China have emphasized the importance of ecological protection. The harmonious coexistence of villages and the natural environment is an important link that cannot be ignored in the planning and design of villages. The planning and design should

be guided by green development, fully consider the protection of the ecological environment, and promote the win-win situation for the village ecology and economy as much as possible.

Improve the living needs and quality of life of villagers: Villagers are the main body of the village, and are the main participants and beneficiaries of the development of the village. The expectation of villagers for the village is an important guarantee for retaining the population, avoiding population loss and realizing rural revitalization. Listening to villagers' demands, improving their living needs and upgrading their quality of life have a positive role on villages. We should attach great importance to the improvement of villagers' living needs and quality of life in village planning and design, so as to enhance the stability and cohesion of rural society.

Focus on cultural heritage and excavation of village characteristics: in the process of rural revitalization, many villages have formed unique village characteristics through excavation and use of their own cultural resources, and rural characteristics are the key to avoiding the phenomenon of homogenization of village development. The planning and design should deeply explore the cultural connotation of the villages, inherit and carry forward the rural culture, and create a rural landscape with local characteristics.

Developing characteristic industries: promoting economic diversification Successful cases of rural revitalization often have a set of successful industrial development model, such as the above Luoyuan County, the start of the town's innovative village agricultural products processing and sales, the development of villages, "e-commerce characteristics of the industrial model". The development of industries is an important factor in promoting the local economy and raising the income of the residents. Reasonable planning and design should focus on the integrated development of industries, so as to enhance the competitiveness of rural industries and broaden farmers' income channels.

To enhance planning leadership and ensure orderly development: scientific and reasonable planning is a prerequisite for rural revitalization. Scientific planning design not only clarifies development goals, development paths and development priorities, but also takes into account the constraints of time, space and resources. In rural planning and design, the leading role of planning should be strengthened to ensure the order and coordination of rural development.

Community participation to achieve the common building and sharing: guiding villagers to actively participate in the construction and development of the countryside, enhancing their sense of belonging and sense of responsibility is an important condition for the formation of a good atmosphere. In recent years, China's rural revitalization of the case more and more emphasis on the residents of the common sharing of the significance of the planning, so as to pay more attention to the construction of the community participation mechanism and encouraging villagers to actively participate in rural construction and management, so as to achieve co-construction and sharing of rural revitalization.

To summarize, excellent planning and design cases in China's rural revitalization projects are characterized by diversity, innovation and sustainability. By summarizing and learning from the experiences and practices of these successful cases, we can better promote the development and revitalization of the countryside in the subsequent planning and design, taking into account the actual situation of the locality, so as to realize the comprehensive prosperity and long-term benefits of the rural areas.

(2). The strategy of endogenous rural development in Germany

The endogenous development strategy adopted by the German countryside has shown remarkable results in optimizing the use of land resources, improving the quality of life of residents, and promoting socio-economic development, and its successful experience has provided a valuable reference for global rural development [36].

In Germany, the boundary between rural and urban areas is not clear, and the term "countryside" was removed from the Guidelines for Spatial Planning issued by the German Ministerial Conference on Spatial Planning in 2006, which made the division between rural and urban areas blurred, but due to the obvious differences in spatial

structure and natural elements between rural and urban areas [37], the definition of rural areas given by the Thünen Institut (Institute for Social Research) is based on the definition of the countryside. According to the definition of rural area given by Thünen Institut, rural area refers to the area with low population density, sparse land for residential development, high proportion of land for agriculture and forestry, farther away from the center of the city, and fewer inhabitants [38]. Therefore, the rural areas in Germany are not only limited to towns and villages, but also include some small and medium-sized cities and the fringe areas around large cities. Here, people do not only rely on agriculture for their livelihood, but also actively participate in a variety of economic activities such as manufacturing and commerce [36].

The strategy of endogenous development of rural areas in Germany, which focuses on the use and revitalization of rural spaces in the existing built environment, emphasizes the importance of taking into account the unique socio-economic and physical characteristics of rural areas in development strategies. In his book *Innenentwicklung im ländlichen Raum*, Gegner analyzes the practical application of endogenous development strategies in the German rural environment, using the town of Ötisheim in Baden-Württemberg as a representative case [39]. The main points mentioned in the paper are as follows. It is proposed that villages need adaptive policy frameworks to enhance the challenges arising from changes in the economic environment, while at the same time identifying opportunities for enhancing local facilities, preserving rural heritage and improving environmental sustainability. Stakeholders are analyzed, including the roles of landowners, local government and residents. Understanding and coordinating these stakeholders is critical to the success of intra-village development. The planning area is clearly delineated, down to size and population density. However, the main purpose is not to save land resources, but to achieve optimal conservation of resources and sustainable development, and to promote the coordinated development of multi-functional village life, production, ecology, and culture through the rational distribution of land and spatial resources. This strategy emphasizes the concept of sustainable development, and requires all participants to conduct in-depth research, strengthen communication, formulate forward-looking plans, and avoid mistakes and wastage in the process of implementation. Through the implementation of the internal development strategy, the town of Ötisheim is beginning to see results. The utilization of land has been effectively increased and the rate of land consumption reduced; the living conditions of the residents have been greatly improved, the emissions from the existing traffic and commercial activities are no longer sufficient to affect the lives of the residents, and the noise from the streets has been greatly reduced due to the rational planning of the surrounding buildings.

Germany, through its endogenous development strategy, has endeavored to improve the sustainability of rural spaces and the quality of life of the inhabitants, so as to make it an area with a balanced development of the living conditions of the inhabitants, the transportation conditions and the employment opportunities. Germany's rural development strategy provides several key lessons that are of good reference value for subsequent rural planning and design. The case can be summarized in the following five points.

Comprehensive strategy: Rural development requires a comprehensive strategy covering infrastructure, economic, socio-cultural and other aspects.

Government support: Government support is key to the implementation of the Rural Development Strategy, both in terms of financial inputs and policy formulation.

Community participation: Ensuring the success of the Rural Development Program requires the broad participation of residents and the active involvement of local communities.

Sustainable innovation: Continuous innovation and the development of new strategies are necessary in order to maintain the vitality and attractiveness of villages.

Conservation of ecology and culture: The preservation of the natural environment and cultural heritage of villages is particularly important for the promotion of rural

tourism and the enhancement of residents' sense of local identity. Therefore, it is necessary to explore and innovate local culture.

Combined with the above two excellent cases, the extraction of operable and replicable strategies and methods can help to solve problems efficiently and optimize the construction and management of rural planning and design. First of all, resident participation is not only a prerequisite step for actual planning practice, but also a key link in design practice. For Urban Marginal Townships, the scope of residents should be extended to local enterprise employees, taking into account the actual feelings of local residents and foreign employees, which is conducive to the retention of the population of industrial townships, thus promoting the development of the local economy and attracting the inflow of foreign talents. Secondly, ecological and cultural preservation also occupies an important position in the actual excellent cases. In the development and utilization of the countryside, a good ecological environment is the foundation of rural development and an important factor in attracting tourists and investment. All the above cases have emphasized that through strong ecological environment protection, enhancing the input-output conversion rate of ecological factors, optimizing the rural industrial structure and increasing the proportion of environmentally friendly industries will help improve the rural ecological environment and promote the development of eco-industries. The protection and restoration of the ecological environment is also of great significance in promoting the construction of rural ecological civilization. In addition, cultural protection is also an indispensable part of rural revitalization. The excavation and innovation of rural culture can help enhance the cohesion and identity of the countryside and promote the improvement and development of the rural governance system. Finally, the development of characteristic industries in the countryside is an important condition for enhancing the competitiveness of the countryside, increasing jobs and increasing the income of residents. Especially for industrial-type townships, how to ensure planning and design to promote industrial upgrading and development, and how to innovate the development of other industries are the key considerations of rural planning and design.

Since rural planning and design has not yet formed a complete system, the content of rural planning and design is extensive and complex. Actual rural cases need to be planned and designed according to local conditions based on experience before summarizing, and strive to achieve rigorous and reasonable design practice.

2. Materials and Methods

2.1 Research design methods

This study firstly clarifies the background of Urban Marginal Townships, then defines the concepts related to Urban Marginal Townships, and understands the characteristics of marginal industrial townships and villages and the urgency of transformational development. The common experience is summarized by the international excellent countryside development cases, and the consensus factor is jointly formed by the experience and knowledge of experts. The fuzzy Delphi method is applied to process the consensus factors in a systematic way, and through several rounds of feedback questions and answers, the scientificity and objectivity of the consensus factors are improved, and the planning and design elements of Urban Marginal Townships are decided. Then, the design elements were transformed into a hierarchical system through fuzzy hierarchical analysis, and the planning and design priorities of Urban Marginal Townships and Villages were obtained through pairwise comparisons.

2.2 The Fuzzy Delphi method

The Fuzzy Delphi method is a method developed by Ishikawa et al. (1993) (Ishikawa et al., 1993), which combines the Fuzzy set theory with the traditional Duffy method. The Fuzzy Delphi method mainly takes into account factors such as uncertainty and semantic changes. The average tendency of the entire population is understood by the (ambiguity) preference of each subject. Zadeh (1975) (Zadeh, 1975) mentioned that since it is difficult for ordinary people to tell the boundaries between concepts, when considering their pros

and cons, they can be represented by such semantics as "strongly agree, agree, common, disagree, very disagree". Then the semantics are converted into fuzzy numbers for analysis. (Pedrycz, Ekel, & Parreiras, 2011) proposed to convert semantic values in a way that can be triangular fuzzy numbers, as shown in Table 1. The analysis steps of the Fuzzy Delphi method are as follows:

First, the i -th scholar on the k -th ,The meaning value of the option is $w_{ik} = (a_{ik}, b_{ik}, c_{ik})$ converted into triangular blurs, and the number of triangulation blurs

for the k -th option can be obtained as follows $w_k = (a_k, b_k, c_k)$

$$a_k = \min \{a_{ik}\}, \quad i = 1, 2, 3, \dots, n$$

$$b_k = (b_{1k} * b_{2k} * b_{3k} \dots * b_{nk})^{1/n}$$

$$c_k = \max \{c_{ik}\}, \quad i = 1, 2, 3, \dots, n$$

Defuzzify, obtain a clear vale and finally set the threshold value α , if $s_k \geq \alpha$, The k -th option is accepted, and the reverse is rejected as form Table1

Table 1. Fuzzy Delphi: A Triangular Fuzzy Number Table of Meaning Variables

Scale	Meaning	Triangular Blur
1	Very disagree	(0, 0, 0.3)
2	Disagree	(0, 0.3, 0.5)
3	Ordinary	(0.3, 0.5, 0.7)
4	Agree	(0.5, 0.7, 1.0)
5	Quite agree	(0.7, 1.0, 1.0)

2.3 Fuzzy Hierarchical Analysis

Given that traditional Hierarchical Analysis cannot overcome the shortcomings of ambiguity in decision making, Buckley (1985) (Buckley, 1985) improved the traditional Hierarchical Analysis method (AHP) of (Wind & Saaty,1980) and proposed a Fuzzy Hierarchical Analysis method (FAHP). That is, triangular fuzzy numbers are substituted into the contrast matrix to deal with the ambiguity problems generated in the decision-making process. FAHP uses the (Interval Value) to replace the (Exact Value) of the traditional level analysis method. This allows experts (Table2) to evaluate issues on a more natural scale when making decisions (Table3 and Table4). The steps of Fuzzy Hierarchy analysis are as follows (Table5):

Table 2. Fuzzy Hierarchical Analysis: Fuzzy Number and Countdown Value for Pragmatic Variables

Scale	Meaning Value (A _{ij})	Blur (F _{ij})	Blur Countdown (f _{ij})
1	It's just as important.	(1,1,1)	(1,1,1)
2	Between being as important and slightly important.	(1,2,3)	(1/3,1/2,1)
3	Slightly more important.	(2,3,4)	(1/4,1/3,1/2)
4	Between a little bit of important and quite important.	(3,4,5)	(1/5,1/4,1/3)
5	It's important.	(4,5,6)	(1/6,1/5,1/4)
6	Between what's important and what's important.	(5,6,7)	(1/7,1/6,1/5)
7	It's pretty important.	(6,7,8)	(1/8,1/7,1/6)
8	Between quite important and extremely important.	(7,8,9)	(1/9,1/8,1/7)
9	It's extremely.	(8,9,9)	(1/9,1/9,1/8)

Table 3. Pair Comparison Matrix

	Option 1	Option 2	Option k-1	Option k
Option 1	1	A_{12}	A_{1j}	A_{1k-1}	A_{1k}
Option 2		1	A_{2j}	A_{2k-1}	A_{2k}
:			1	A_{ik-1}	A_{ik}
Option k-1				1	A_{k-1k}
Option k					1

Table 4. Fuzzy Comparison Matrix

	Option 1	Option 2	Option k-1	Option k
Option 1	1	F_{12}	F_{1j}	F_{1k-1}	F_{1k}
Option 2	f_{12}	1	F_{2j}	F_{2k-1}	F_{2k}
:	f_{1j}	f_{2j}	1	F_{ik-1}	F_{ik}
Option k-1	f_{1k-1}	f_{2k-1}	f_{ik-1}	1	F_{k-1k}
Option k	f_{1k}	f_{2k}	f_{ik}	f_{k-1k}	1

Calculate the geometric mean of each option from Table 5 and the weight of each option, as shown in Table 6, to understand the priority in terms of importance and finally resolve their ambiguous issues similarly.

Table 5. Option Geometry Average and Option Weight

Scale	Option Geometry Average	Option Weights
Option 1	$M_1 = (1 \otimes F_{12} \otimes \dots \otimes F_{1k-1} \otimes F_{1k})^{1/k}$	$W_1 = M_1 \otimes (M_1 \oplus M_2 \oplus \dots \oplus M_{k-1} \oplus M_k)^{-1}$
Option 2	$M_2 = (f_{12} \otimes 1 \otimes \dots \otimes F_{2k-1} \otimes F_{2k})^{1/k}$	$W_2 = M_2 \otimes (M_1 \oplus M_2 \oplus \dots \oplus M_{k-1} \oplus M_k)^{-1}$
:	$M_i = (f_{1j} \otimes f_{2j} \otimes \dots \otimes F_{ik-1} \otimes F_{ik})^{1/k}$	$W_i = M_i \otimes (M_1 \oplus M_2 \oplus \dots \oplus M_{k-1} \oplus M_k)^{-1}$
Option k-1	$M_{k-1} = (f_{1k-1} \otimes f_{2k-1} \otimes \dots \otimes 1 \otimes F_{k-1k})^{1/k}$	$W_{k-1} = M_{k-1} \otimes (M_1 \oplus M_2 \oplus \dots \oplus M_{k-1} \oplus M_k)^{-1}$
Option k	$M_k = (f_{1k} \otimes f_{2k} \otimes \dots \otimes f_{k-1k} \otimes 1)^{1/k}$	$W_k = M_k \otimes (M_1 \oplus M_2 \oplus \dots \oplus M_{k-1} \oplus M_k)^{-1}$

The research adopts a three-round approach to collect experts' opinions and define the planning and design elements of Urban Marginal Townships and Villages. (1) The first round invites experts to conduct in-depth interviews with case summaries of excellent experiences by using semi-structured interviewing to obtain relevant design opinions; (2) The second round will After organizing and analyzing the design opinions of the first

round, the design element questionnaire is constructed and scholars of rural construction and township creation are invited to fill in the questionnaire; (3) the third round analyzes the results of the questionnaire of rural construction and township creation and determines the final design elements of the rural planning of Urban Marginal Townships and Industrial Townships, which can be used in the subsequent research to suggest the design factors to be considered.

The Materials and Methods should be described with sufficient details to allow others to replicate and build on the published results. Please note that the publication of your manuscript implicates that you must make all materials, data, computer code, and protocols associated with the publication available to readers. Please disclose at the submission stage any restrictions on the availability of materials or information. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited.

Research manuscripts reporting large datasets that are deposited in a publicly available database should specify where the data have been deposited and provide the relevant accession numbers. If the accession numbers have not yet been obtained at the time of submission, please state that they will be provided during review. They must be provided prior to publication.

Interventionary studies involving animals or humans, and other studies that require ethical approval, must list the authority that provided approval and the corresponding ethical approval code.

3. Results

In the first round of semi-structured interviews, experts were selected from all levels of government officials directly or indirectly involved in the planning, as well as from the top management of the local enterprises involved, including two senior rural planning designers, two government officials, four bosses of the neighboring factories and three representatives of the local residents, for a total of 11 experts. The main objective is to summarize the case design factors and the results of the expert interviews to extract the ideal initial planning and design objectives for Urban Marginal Townships, as shown in Table 6.

Table 6. List of Summary of Key Elements of Round 1 Delegate Interviews

	Average age	Identities	Contents Collation
Representative A	32	Senior Rural Planning Designer	Rural villages on the fringe of urban industry should pay attention to the protection of the environment, reduce ecological disturbances, and seek to create a balance in the region, such as the development of cultural tourism and leisure industries, the remediation and design of public spaces, assisting villagers to improve the living environment, thinking about the possibility of adaptive reuse, and the consideration of universal design.
Representative C	35	Government Officials	How to make the countryside economy be upgraded, so as to increase the income of the residents, is an important part of the countryside planning and design.

Representative E	42	Neighboring factory owners	The improvement of leisure facilities around the village can be a place of fellowship or study to retain workers from outside the province, in order to realize the healthy development of villages on the edge of the city. More than anything, they would like to have employment at their doorsteps
Representative I	40	Representatives of local residents	and for the village to provide more jobs. There are places for entertainment or places for children to play.

The expert interviews obtained in the first round were organized into design elements, and combined with excellent cases from China and Germany, 18 design elements can be initially derived, as shown in Figure 1. Based on these elements, the first questionnaire can be designed to be scored by the scholars of rural construction and rural development, and the measurement tool is based on the Likert Scale (LS) 5-item scale of Strongly Agree, Agree, Ordinary, Disagree, and Strongly Disagree, which gives 5, 4, 3, 2, and 1 points, respectively, and according to these five semantic scales to reflect the respondents' emphasis on each factor indicator and to determine whether these factors can be used in subsequent research.

The first round of questionnaire analysis and summarization, rural construction and rural creation of a total of 12 scholars, completed 12 valid questionnaires, for the study of the initial design factors by experts and scholars to carry out aptitude assessment, the period of time can be consistent with the design of the purpose of the study, the threshold value of the researcher to the main subjective judgment, should not be too high, should not be too low, in order to obtain the appropriate and important and sufficient number of assessment indicators, generally take 0.6 to 0.8 (Hsu Chun and , 1998), as the design factor indicator of the second questionnaire. The structural analysis of the first questionnaire shows that the weights of the assessment factors are all above 0.65, indicating that the scholars of township creation agree that the consensus of the design factors is high, and that they can be used as the design elements of the rural design planning of Urban Marginal Townships for the next assessment, and the results are shown in Table 7

Table 7. Questionnaire for Scholars of Rural-Related Design

No	Design Factors	Mean value	Weights
1	Ecological conservation is a factor to be considered in the rural planning and design of urban fringe towns and villages.	4.38	0.88
2	Community participation is an important aspect of rural planning and design in marginalized urban townships and villages.	4.23	0.85
3	Planning leadership is a necessary element of rural planning and design in marginalized townships and villages.	4.23	0.85
4	Improving villagers' needs can promote the science of rural planning and design in marginalized urban towns and villages.	4.31	0.86
5	Planning and design of urban fringe townships and villages should consider the development of specialty industries.	4.54	0.91

6	Planning and design of urban fringe townships and villages should consider the development of specialty industries.	4.31	0.86
7	Designing adaptive policy frameworks can ensure the integrity of rural planning and design in marginalized urban towns and villages.	4.00	0.80
8	Analyzing stakeholders' ability to safeguard the rigor of planning and design in marginal urban townships and villages.	4.00	0.80
9	Clear delineation of planning areas is a necessary component of rural planning and design in marginalized urban towns and villages.	4.00	0.80
10	Planning and design of urban fringe townships and villages should consider enhancing the rural economy.	4.31	0.86
11	Planning and design of urban fringe townships and villages should take into account the need to increase jobs.	3.77	0.75
12	The development of cultural tourism and leisure industry is necessary for the planning and design of urban fringe townships and villages.	3.62	0.72
13	Improving the living environment of villagers is necessary for the planning and design of marginalized townships and villages.	3.85	0.77
14	Improving peripheral open space facilities is necessary for the planning and design of urban fringe townships and villages.	3.92	0.78
15	Rectification of public space design is necessary for the planning and design of urban fringe townships and villages.	4.08	0.82
16	Planning and design of urban fringe townships and villages should consider the provision of children's recreational areas.	3.62	0.72
17	Planning and design of urban fringe townships and villages should consider the provision of places for male and female employees to socialize.	3.31	0.66
18	Inheritance of rural culture is necessary for the planning Average values and design of urban fringe townships and villages.	4.15	0.83
Average values		4.03	0.81

The design elements to be analyzed were determined through the first online questionnaire survey mentioned above. Next, the second questionnaire survey was conducted, and the main questionnaire respondents included: rural design experts, rural design scholars, and community master builders. Based on the results of the fuzzy Delfy method of analysis, it was constructed as 1. sustainable urban fringe development; 2. rural regeneration and cultural preservation; 3. agricultural diversification and the food

industry; and 4. community participation and management; four dimensions, and 18 assessment indicators, as shown in Figure 1, were created as Fuzzy Hierarchical Analysis Questionnaire. The relative and absolute weights of the design elements of the industrial marginalized villages were explored. The questionnaire was filled out by experts using a two-by-two comparison method with 1 to 5 evaluation scales. A total of 39 questionnaires were distributed, 37 were returned, and 37 were valid.

Insert Figure 1 Classification of Rural Planning and Design Elements for Urban Marginal Townships

The results of the second questionnaire were statistically analyzed, and the weights of the design factors were calculated by the fuzzy Delphi method (as shown in Fig. 2), according to which it can be obtained that the importance of rural planning and design of Urban Marginal Township industrial townships in the following order: 1. rural regeneration and cultural protection 2. community participation and management 3. sustainable urban fringe development 4. agricultural diversification and food industry. Among them, the evaluation factor indicators of rural regeneration and cultural preservation are in the following order of importance: Exploring the characteristics of the countryside > Inheriting the rural culture > Analyzing the stakeholders For the evaluation of community participation and management, the order of significance is as follows: Improving public facilities > Planning leadership > Rectification of public space design > Community participation > Designing an adaptive policy frameworks > Clearly delineating the planning areas. For the evaluation of sustainable urban fringe development, the order of importance of the factors is: Ecological preservation > Improvement of the villagers' living environment > Improvement of surrounding leisure facilities > Increasing jobs > Providing a place for children's recreation > Provide a place for male and female employees to socialize. Among the indicators for the assessment factor of agricultural diversification and food industry, the order of importance of their impacts is as follows: Upgrading the countryside's economy > Development characteristic Industries > Development of cultural tourism and leisure industry.

Insert Figure 2 Urban Marginal Township Industrial Planning and Design

Element Hierarchy Analysis Structure and Results

The first stage of the fuzzy defuzzy method to get the consensus factor has four major facets, which are: sustainable urban fringe development, rural regeneration and cultural preservation, rural regeneration and cultural preservation, community participation and management. There are eighteen consensus factors: ecological protection, increasing jobs, improving the villagers' living environment, improving the surrounding leisure facilities, providing a place for children's recreation, providing a place for male and female employees to socialize, improving public facilities, planning leadership, rectification of public space design, community participation, designing an adaptive policy frameworks, clearly delineating the planning areas, exploring the characteristics of the countryside, analyzing the stakeholders, inheriting the rural culture, upgrading the countryside's economy, developing characteristic industries, developing the culture of tourism and leisure industry, In the second stage, the relative weights are analyzed using the fuzzy hierarchical analysis method to analyze the importance of the relative weights, in order of weights 1. rural regeneration and cultural preservation > 2. community participation and management > 3. sustainable urban fringe development > 4. agricultural diversification and food industry, and its four dimensions are analyzed as follows:

- Rural regeneration and cultural preservation

This facet is the first design factor to be considered in rural design. "Exploring Character" is of considerable importance in the assessment of rural regeneration and cultural preservation, mainly because rural character is the embodiment of the uniqueness and cultural identity of a region. The main reason is that rural characteristics are the embodiment of a region's uniqueness and cultural identity. The uniqueness and

attractiveness of the countryside can be enhanced through in-depth excavation and display of its unique features and cultural elements. Bourdieu once mentioned in his theory of cultural capital that "cultural resources and traditional customs are intangible assets of a place, which can be converted into economic capital." This can fully explain that the uniqueness of rural characteristics is a key factor to attract tourists and investors, and can bring significant economic benefits. Stakeholder analysis involves the interests and needs of all parties involved in the project, which must be analyzed and coordinated comprehensively in order to help promote the smooth implementation of the project. Therefore, "exploring characteristics" can be considered as a prerequisite for analyzing stakeholders. Analyzing stakeholders is considered to be of equal importance to the weighting of cultural heritage and conservation. This may be due to the following reasons: firstly, effective stakeholder analysis facilitates the formulation and implementation of cultural protection policies, and the protection of cultural heritage requires the participation and support of a wide range of stakeholders; and secondly, heritage culture and preservation enhances the sense of cultural identity and cohesion of the community, and the effective participation of stakeholders is key to the realization of this goal. The two exist in an interdependent relationship, complementing and fulfilling each other.

- Community participation and management

Villagers are the main characters of villages, and their needs are considered to be the most important in village planning and design. Of course, Urban Marginal Township villages are even more so. Although scientific planning leadership can provide a clear direction and framework for community development and ensure rational allocation and efficient utilization of resources. However, villagers are the main beneficiaries and participants in the countryside, and their needs are directly related to the development and stability of the community, so meeting their needs is the core objective of community planning and governance. In addition, the design of public space, community participation, adaptive policy frameworks, and the division of planning areas all directly affect or serve the needs of villagers. Together, these factors aim to ensure the long-term stability and sustainable development of communities by meeting residents' needs, providing clear planning directions, optimizing the design of public spaces, enhancing community participation and designing adaptive policy frameworks.

- Sustainability of urban fringe development;

Conservation of ecology is the basis for the long-term development of urban fringe areas, ensuring the sustainability of the regional environment and the health of residents. Improving the living environment of residents and improving the surrounding leisure facilities are of secondary importance, mainly reflecting the direct impact of both on the quality of life and well-being of residents, while playing an indirect role in the sustainable development of marginal urban areas. Providing places for children's recreation and increasing jobs opportunities are of equal importance, reflecting the experts' dual focus on family life and economic development.

- Agricultural diversification and the food industry

The economic foundation determines the subsequent construction of the village. A stable economic foundation is the prerequisite for the development of all other industries. Only when the economic foundation is improved, can there be enough resources and funds invested in the development of specialty industries, and then the specialty industries cover the amount of development of cultural tourism and leisure industries. Therefore, there is a strong logical relationship between the comparison of agricultural diversification and food industry assessment factors. Firstly, a stable economic foundation is laid by prioritizing the upgrading of the rural economy; subsequently, specialty industries are developed to enhance the market competitiveness and brand effect of the countryside; finally, economic diversification is further expanded through the development of cultural, tourism and leisure industries to realize the overall prosperity and sustainable development of the countryside. This logical sequencing reflects

systematic consideration of economic foundation, industrial competitiveness and economic diversification, and ensures a gradual and comprehensive balance in rural development.

This study emphasizes the importance of rural regeneration and cultural preservation, community participation and management, sustainable urban fringe development, and agricultural diversification and the food industry in rural development, and analyzes the order of importance of each of the elements under the construct, which are intertwined and interact with each other to form the multidimensional considerations required for rural development. It is worth noting that, although the element of "providing a place for male and female employees to socialize" under the sustainable Urban Marginal Township development construct is at the bottom of the ranking, due to the special characteristics of Urban Marginal Townships, the authors found that workers' need for social interaction is urgent, and for the townships with a large number of industrial clusters, the authors have found that the socialization of workers in the villages is very important. In villages, there are many young men and women from different provinces, providing places for male and female employees to socialize is a factor that cannot be easily ignored in planning and design. This is what is emphasized in this paper, and it is hoped that through the research in this paper, it will draw the attention of project experts and scholars to improve and enrich the content of planning and design of industrial townships and villages on the urban fringe.

Conclusion

With the continuous expansion of cities, the townships and villages in the fringe areas are gradually facing more problems. Urban Marginal Townships and villages, as an important node in the integrated development of "city-rural-village" [16], are bound to be upgraded in the direction of more reasonable and scientific planning and design. Therefore, it is very necessary to explore the related planning and design issues of such townships and villages. In this paper, by using the fuzzy Delphi method and fuzzy hierarchical analysis method, the assessment factors in the planning and design of Urban Marginal Townships and Villages are deeply analyzed and compared, and then the consensus factors in the planning and design of Urban Marginal Townships and Villages are systematically processed and analyzed, and the planning and design framework is formed in a scientific and practicable way. As for rural regeneration and cultural conservation, this paper emphasizes the importance of excavating rural characteristics and inheriting cultural conservation, and ensures the effective implementation of cultural heritage conservation policies through a comprehensive analysis of stakeholders. Research on community participation and management shows that meeting villagers' needs and scientific planning leadership are the core of realizing long-term stability and sustainable development of the community. The prioritization of sustainable urban fringe development further emphasizes the fundamental role of ecological conservation and improvement of residents' living environment. The ranking of assessment factors for agricultural diversification and food industry reflects the logical relationship and interdependence between upgrading the economic base of villages, developing specialty industries and promoting cultural tourism and leisure industries.

In summary, this study provides a new perspective for the planning and design of urban marginal industrial townships and villages with a comprehensive and scientific theoretical basis and research method, which has important academic value and practical application significance. Future research can further conduct empirical analysis based on specific cases to verify and improve the planning and design framework proposed in this paper, and provide more powerful support for the realization of comprehensive prosperity and sustainable development of urban marginal villages.

Supporting information

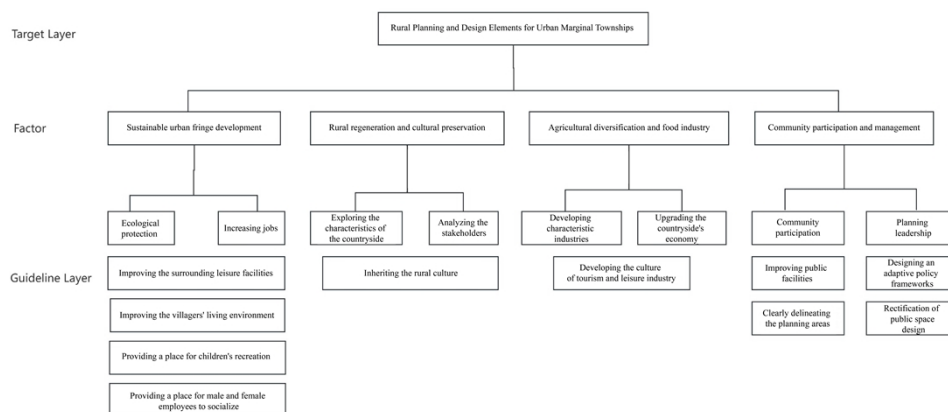


FIGURE 1
Classification of Rural Planning and Design Elements for Urban Marginal Townships

Figure 1. Classification of Rural Planning and Design Elements for Urban Marginal Townships

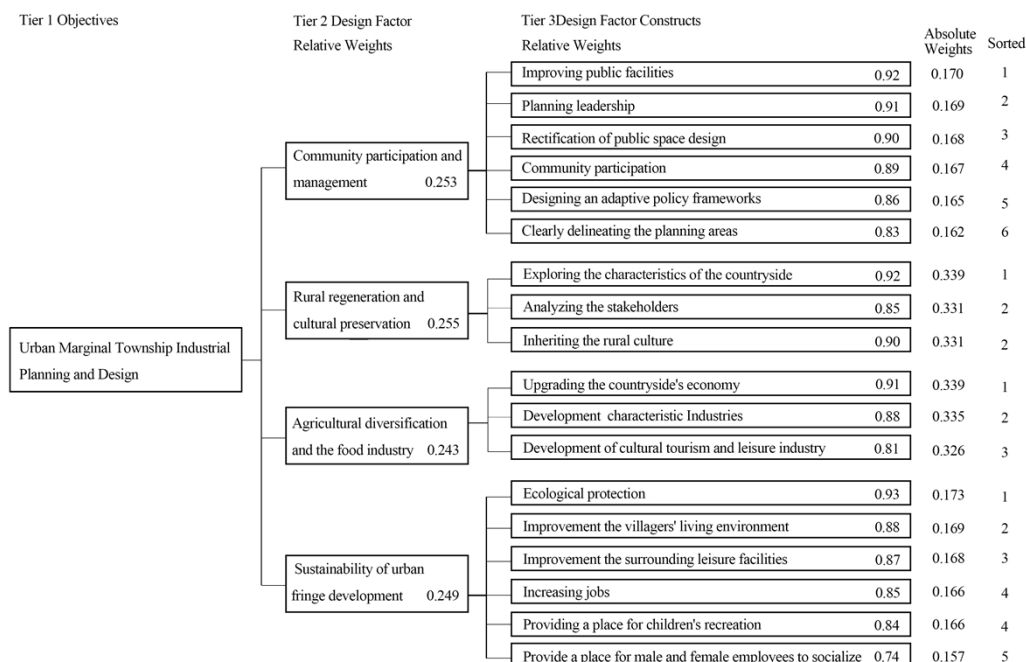


FIGURE 2
Urban Marginal Township Industrial Planning and Design Element Hierarchy Analysis Structure and Results

Figure 2. Urban Marginal Township Industrial Planning and Design

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