Journal of Infrastructure, Policy and Development 2024, 8(1), 2603.
https://doi.org/10.24294/jipd.v8i1.2603

Article

Research on village classification and development based on particle swarm optimization model: Xiecun Township, Yuanping City, in Shanxi Province, China

Xiaoting Ma*, Nangkula Utaberta, Nadzirah Zainordin

School of Architecture and Built Environment, Faculty of Engineering and Built Environment, UCSI University, Kuala Lumpur 56000, Malaysia

*** Corresponding author:** Xiaoting Ma, 1002164069@ucsiuniversity.edu.my

CITATION

Ma X, Utaberta N, Zainordin N. (2024). Research on village classification and development based on particle swarm optimization model: Xiecun Township, Yuanping City, in Shanxi Province, China. Journal of Infrastructure, Policy and Development. 8(1): 2603. https://doi.org/10.24294/jipd.v8i1.2603

ARTICLE INFO

Received: 15 August 2023
Accepted: 18 September 2023
Available online: 18 December 2023

Abstract: China's village development confronts substantial challenges, inefficient land use due to the scattered village layout, sluggish development of village industries, and lack of proper planning for village development and construction, etc. Scientific classification of villages and village-based policy is the key to address these challenges. This study employs cell phone signaling big data to construct a population flow model based on particle swarm optimization algorithm This model takes into account spatial driving force and social connection strength as dual conditions. Also, it analyzes the settlement redistribution optimization scheme under the model through empirical research on Xiecun Township of Yuanping City, Shanxi Province, in order to classify villages scientifically and apply different strategies to village development according to the classification results. The findings of the study indicate that the area characterized by the densest distribution of optimized particle clusters, with good land conditions and high economic income, are classified as "cluster-enhanced villages". Regions with the densest distribution of the initial particle distance factor and the densest distribution of optimized particle clusters are closer to the urban centers, which are better positioned to take advantage of the city's financial and technological resources and continuously improve the added value of agricultural products, so they are classified as "peri-urban integrated villages". Areas characterized by sparse distribution of optimized particle clusters need to actively cultivate the advantageous and characteristic industries in the countryside, and bolster transportation conditions and the protection of local culture, so as to realize the green development of urban and rural regional economy. Such areas are classified as "characteristic conservation villages". In areas without optimized particle cluster distribution or areas with extremely sparse distribution of optimized particle clusters, the rational layout of urban and rural settlement spatial organization should be vigorously promoted, with emphasis on the enhancement of ecological environment, and they are classified as "relocated and annexed villages". According to the results of village classification, corresponding strategies to promote the development of different types of villages are proposed in terms of spatial optimization, industrial upgrading and planning.

Keywords: big data; village classification; development strategies; particle swarm optimization

1. Introduction

Rural areas are the backbone of urban construction and an integral part of social progress and national development (Li et al, 2022). Rural development is not only the focus of multidisciplinary research at home and abroad, but also a major strategic issue related to national economy and people's well-being (Ma et al., 2019). Both developed and developing countries have grappled or are grappling with problems such as rural depopulation and rural decline (Liu and Li, 2017). Currently, China is also facing the same problems of unbalanced urban-rural development and insufficient rural development. The promotion of rural development has become a key issue in the new era of Chinese society (Chen et al, 2019). As such, the 19th Party Congress Report proposed the rural revitalization development strategy to foster the harmonized progress of urban and rural regions (Ye and Liu, 2020). However, with the acceleration of the urbanisation process, the differences in location conditions, village size, and resource endowment between villages in the same region have become increasingly pronounced. A singular policy or specific development model is no longer suitable for guiding rural development, and categorisation of villages according to village differentiation has become the primary framework for village development (Sikorski et al., 2020). To meet this end, in 2018, the Central Committee of the Communist Party of China (CPC) and the State Council issued the National Rural Revitalisation Strategic Plan (hereinafter referred to as the "Plan"). This Plan introduced the classification of villages into four types, namely, cluster enhanced, peri-urban integrated, characteristic conservation, and relocated and annexed. These classifications are intended to provide a basis for the type of rural classification in the light of the differences in the system of the rural area. However, as a top-level design, the Plan specifies the types of village classification in China, it does not come up with specific classification methods. Instead, exploring scientific methods of village classification and proposing classification development strategies are very important for the sustainable development of rural areas in China (Li et al., 2022).

At present, the scientific classification of villages has become the focus of scholars' work. Scholars have launched a series of discussions and studies on the classification and development of villages. Globally, Christaller (1966), a renowned German urban geographer, proposed the central location theory after studying German villages. He contended that different villages have different levels of development and spatial distributions. Bogdanov et al. (2008), van Eupen et al. (2012), Raharja et al. (2020) and Molestina et al. (2020) employed quantitative research methods involving decomposition and induction to identify village classifications based on the identification of natural endowments, economic and social structures. Chinese scholars have also conducted extensive research on village classification methods in China under the guidance of the Plan. Li et al. (2020) devised a village classification model and used fishing nets to classify villages qualitatively, establishing an effective way to classify villages in China. Tian et al. (2021) used the GWR model to draw suburban boundaries at the village scale for village classification definition. Liu et al. (2022) used the AHP method to determine the index weights and build a model to quantitatively assess the vitality of villages, and then proposed a village classification for the study area. Finally, Li et al. (2022) used the AHP method to calculate the village development potential scores and constructed a village classification model.

Current scholars' research has laid the foundation and conceptual framework for the development of this paper. As the Plan does not specify the village classification method, scholars are still exploring the specific classification methods for the four village types involved in the Plan. This exploration has revealed certain research gaps. The current research methods are mostly single quantitative or qualitative methods.

Building upon these precedents, this paper attempts to use mobile phone signalling data on the basis of previous research, to construct particle swarm optimization algorithm model This model operates under the dual conditions of spatial driving force and strength of social ties from the perspective of big data. By doing so, the paper seeks to provide new ideas for village classification methods, and to put forward the development strategies of different types of villages based on the results of village classification. What is more, it strives for providing the spatial optimisation of villages and the industrial upgrading, planning, as well as systematic basis for village space optimisation, industrial upgrading and planning.

2. Area situation of research

2.1. Scope of research

The study focuses on Xiecun Township, Yuanping City, Shanxi Province as the research area, with an area of 62 square kilometers (see **Figure 1**). Xiecun village is close to the urban area, which exhibits poor agricultural conditions, unbalanced rural development, and possesses a relatively comprehensive platform data, etc. These attributes can better ensure the comprehensiveness of data acquisition.

Figure 1. Regional location of the study area.

2.2. Regional overview

Xiecun Township is located 7.5 km to the west of Yuanping City, Shanxi Province. It adjoins Daniudian and Xizhen Townships to the north, Yanzhuang Wangjiazhuang Township to the south, Xinyuan Township to the east, and Loubanzhai Township to the west. The township includes 17 villages, housing 4114 households and a population of 13,012 people.

The township grapples with challenges such as barren land, limited water sources, and nine droughts in ten years. It is a township with the least favorable production conditions in the city. There are three rivers (Beigang River, Ruzhuang River, Shengou River), two beams (Snake and Lion Liang, Maerliang), one mountain (Heishi Nao) and one river in the territory, spanning an altitude range of 800–1200 m.

2.3. Realistic dilemma

Through on-the-spot surveys of all villages in Xiecun Township and face-to-face interviews involving more than 200 villagers, it was found that Xiecun Village is facing the following problems in the development of villages.

2.3.1. Inefficient land use results from scattered layouts

The village landscape is characterized by a multitude of small-scale, scattered villages with an uneven spatial distribution, which contributes to obvious regional differences. Many villages, especially those with poor conditions and limited resources are disappearing. The majority of these villages have become “hollow villages”, “dilapidated villages” and “elderly villages”. What is more, frequent production interruptions and semi-stop production of industrial and mining enterprises are frequent bring about a common issue if inefficient land use.

2.3.2. Slow development of village industries

Economic progress in the village has remained sluggish. As such, it is apparent that the per capita net income of farmers is unevenly distributed. The processing and transformation capabilities remain inadequate, and most of them still sell raw agricultural products such as grains, fruits, and medicinal herbs. The structure of agricultural products is far removed from proper, while agricultural quality still remains insufficient. Moreover, the development of new agricultural industries and new business models lags behind, which leads to a short suburban agricultural industry chain. What shall be noticed is that, leisure agriculture and rural tourism have been witnessing limited scale and sophistication, followed by low-level and homogeneous competition.

2.3.3. Lack of planning for village development and construction

Most villages have not established systematic, clear and practical planning, leading to improper and unregulated land utilization practices. There exists an inadequacy in long-term planning for residential areas, industrial development space, farmland preservation zones, and ecological protection areas. The rural landscape lacks a unified plan when it comes to a thousand villages. In most rural regions, when the government arranges for the construction of infrastructure or public service facilities, it often prioritizes individual facilities without considering the rational arrangement of these assets within the village. As such, comprehensive construction plans usually cannot be delivered. Therefore, an effective, unified and coordinated medium and long-term development plan is seldom realized. When implementing projects, various industry departments often operate independently, lacking overall consideration and collaborative efforts, which not only results in unreasonable layout of various facilities, but potential investment inefficiencies.

3. Methodology

3.1. Particle swarm optimization (PSO)

Particle Swarm Optimization (PSO) was proposed by Kennedy and Eberhart in 1995 after comprehensively studying the rules of foraging behavior in birds. The theoretical basis of its algorithm is to regard as each particle as an individual in the bird group, equipping each particle with memory capabilities. PSO seeks the most optimal solution through the interactions with other particles in the particle group, and at the same time make itself in the optimum solution. In the algorithm, three conditions must be satisfied. To be more specific, conflict avoidance is essential as the group moves in a certain space. Each individuals can decide their movements, however, they cannot affect the movement of others, so as to avoid collisions and disputes. Secondly, speed matching is of great importance for the reason that individuals must synchronize the moving speed with the group's center regardless of the direction, distance and speed. Such requirement comes from their necessity of working together. The third condition is the center of the group. The individual will move to the center of the group and cooperate with the center of the group to advance towards the goal.

In the current study, the Particle Swarm Optimization algorithm has been applied to various industries that require spatial location assignment. Ghaderi et al. (2012) addressed the continuous location allocation problem without tolerance and proposed a PSO algorithm. This algorithm serves to determines the optimal facility locations and customer allocations to these facilities. Also, Xu et al. (2022) employed the PSO algorithm in short-term flood forecasting. Li et al. (2022) leveraged the PSO algorithm for the parameter extraction of solar photovoltaic model.

Taking Xiecun Township, Yuanping City, Shanxi Province as an example, this study uses Particle Swarm Optimization to establish a population flow model for the purpose of achieving the optimal solution for rural layout allocation. Hence, this approach copes with the historical dominance of human factors in rural spatial layout where there was no enough objective evidence. As such, it improves the accuracy of the optimized layout of village settlements and provides targeted guidance for village development.

3.2. Data sources

In Xiecun Township, the resident population totals 13,012 people. For the purpose of indentify the total number of cell phone users in Xiecun Township, this study designed the questionnaire (**Table 1**) and by the township's 17 village committees for the full coverage of the questionnaire distribution and recycling. Meanwhile, in order to ensure the authenticity and effectiveness of the, sampling visits were conducted. Sampling results confirmed a 100% authenticity rate for the questionnaires. According to the questionnaire statistics, Xiecun Township cell phone users amounted to 10,035, of which 80% of the villagers choose to use the services provided by mobile operators, 15% of the villagers prefer the services provided by Unicom operators, 5% of the villagers choose the services provided by telecom operators.

Table 1. Questionnaire content.

1. Your age is ☐ Under 20 years old ☐ 20–40 years old ☐ 41–60 years old ☐ Over 60 years old
2. Are you a mobile phone user ☐ Yes ☐ No
3. If you are a mobile phone user, your mobile phone operator is ☐ Mobile ☐ Unicom ☐ Telecom
4. If you are a cell phone user, and you have used the cell phone for a period of ☐ Within six months ☐ Six months to one year ☐ More than one year

Cell phone signalling data consists of the communication data between the cell phone users and the transmitting base station or micro station. Since the location of the communication base stations are fixed and known, they reflects the user's location. As such, the cell phone signalling data field always includes the time and location information. Therefore, the research data of this study is based on the cell phone signalling data of Xiecun Township. Furthermore, the basic format of the raw data contains the information of cell phone IMSI number, timestamp, base station number, event type, and cell phone belonging to the place, etc. In this study, 10,100 cell phone IMSI numbers of Xiecun Township base stations are collected from three major operators, however, since some of the data is generated by way of Xiecun Township, the data needs to be processed and screened Cell phone IMSI numbers with 60% timestamps within Xiecun Township during the period of 01/06/2022-01/01/2023. 9987 valid data were counted, accounting for 99.52% of the total cell phone subscribers in Xiecun Township.

3.3. Model construction

Mobile phone signaling data can ideally reflect the social connections between villages and represents one of the key factors in the layout of rural population and residential areas. This study aspires to establish a relationship between the strength of social connections among villages based on mobile phone signaling data and the layout of rural settlements through particle swarm optimization (PSO). Notably, the study also investigates the particle flow process under the joint action of the two (**Figure 2**).

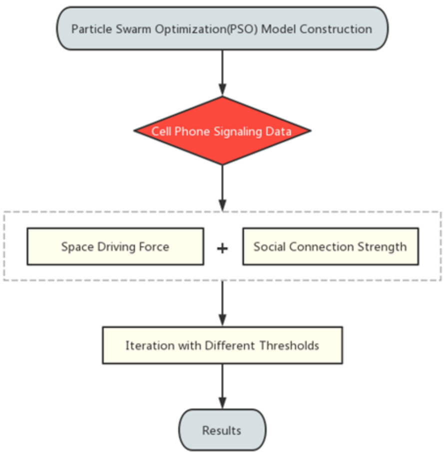

Figure 2. PSO Model Construction Logical framework.

The village population flow model (**Figure 3**) is constructed to combine the optimization of rural settlement layout based on PSO with the strength of social ties between villages based on cell phone signaling data, and seeks for the particle updating process under the joint effect of the two. In the particle swarm optimization algorithm, each particle represents an alternative rural settlement redistribution scheme. In addition, each particle is depicted as a vector, where one dimension being the vector is actually at (i, j). These particles have their own velocities and positions to represent their positions in the search space. Spatial and social optimization are delivered to identify the best visiting locations for individuals and entire populations. During optimization, particles continue to move toward the optimal solution based on their own best-known position and the best-visited position of the entire swarm. Movement persists until a termination condition (maximum iterations or threshold) is met. At each iteration, the particles update their speed and position as follows:

$$Vi = w \cdot Vi + c1 \cdot r1(Pbesti - Xi) + c2 \cdot r2 \cdot (Gbest - Xi) \quad (1)$$

$$Vi = Vi + Xi \quad (2)$$

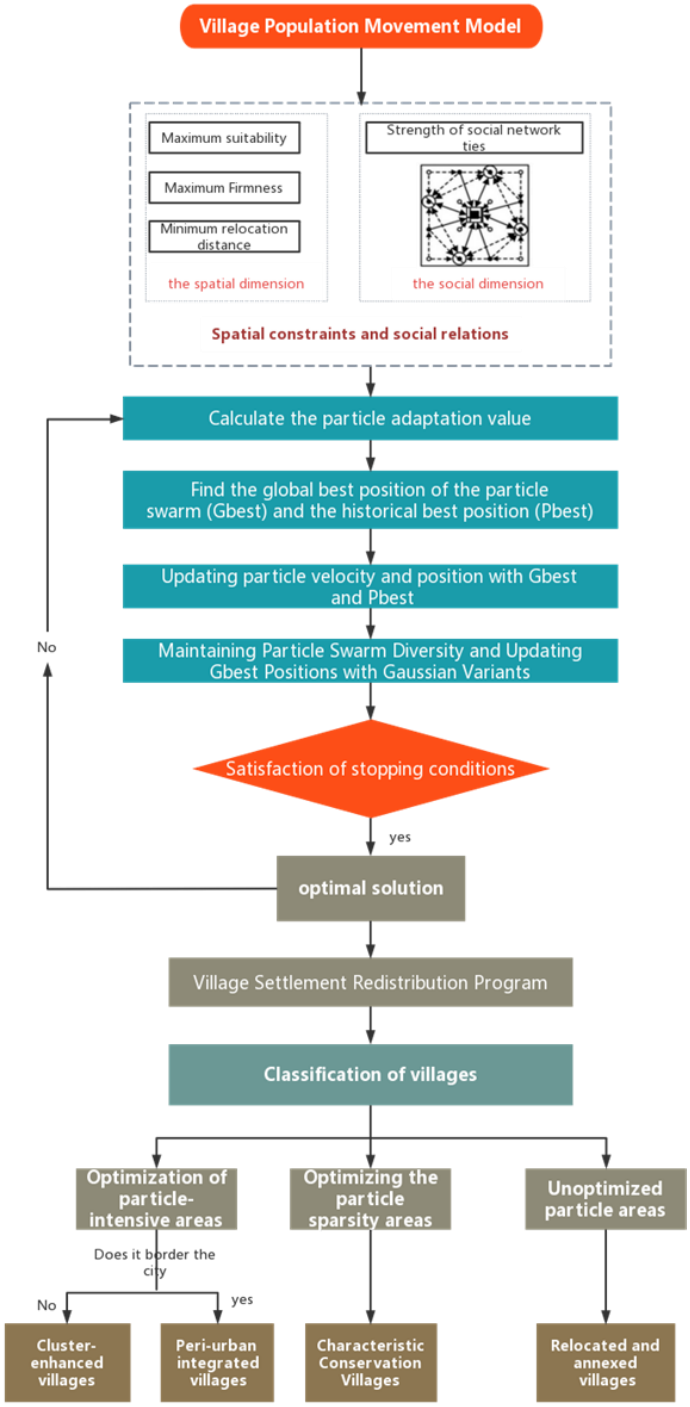

Figure 3. The relationship between particles distribution and land use suitability.

Under the Gaussian distribution, the position of the global optimal particle is randomly updated according to the probability in each iteration. This update process is aimed at obtaining the optimal solution for adjusting the layout of population and rural settlements. The population flow model, based on PSO algorithm, will obtain the final particle distribution number of the village by adjusting the position of particles to the optimal solution. This final distribution number can predict the redistribution scheme of village settlement layout, forming reference basis for village classification. Combined with the Village Revitalization Strategic Plan (2018–2022) issued by the Central Committee of the Communist Party of China and the State Council, villages are categorized into four types: Agglomeration and enhancement type, suburban integration type, characteristic protection type, and relocation and annexation type. In the population flow model, villages with a large amount of optimized particle aggregation reflect a strong likelihood of future population influx, which is a potential area for future development. These villages are suitable to be classified as the agglomeration and enhancement type and the suburban integration type based on the geographic location of the village. In contrast, the villages with a scarce amount of optimized particle aggregation or no particle aggregation reflect the trend of the future population of the village is lost, and this type of village is suitable to be classified as the character protection type and the relocation and annexation type based on the characteristics of the village. These villages are suitable to be categorized into the character protection type and the relocation and annexation type according to their unique characteristics and circumstances.

4. Results

4.1. Spatial driving force

The formation, development and evolution of the layout of village settlements are gradually formed under the influence of natural geographical conditions. In general, the layout of village settlements mainly reflects the strength of social ties, the closeness of which primarily depends on the suitability of village land, the distribution of the population and the distance from the city. Each of these factors plays a different role in the process of forming the spatial pattern.

Xiecun Township is located in a mountainous and hilly area, where the relatively challenging natural environment greatly limits the choice of villagers' settlements. Due to the limited economic and technological conditions, the impact of natural environmental factors is particularly pronounced. Villagers are compelled to adapt to the local environment and harmonize with it due to these constraints. Therefore, in the process of changing and developing village settlements, the suitability of land use stands as one of the primary considerations. At the same time, agricultural culture exerts a significant impact on the transformation and development of village settlements. Rural areas place strong emphasis on the concept of "surname", forming families with "surname", which later evolve into settlements. Large settlements often have stronger production capacity and can generate more wealth. Long term settlement-based production work leads to the establishment of stable village communities. Transportation location is also an important factor affecting the transformation and development of village settlements. The rapid urbanization process has intensified the "siphon effect" of cities on rural areas, reducing the distance between cities and rural areas through urban road construction, Importantly, this has promoted the rapid flow of people, logistics, and information. The transportation and economic advantages of the urban central area further drive the gathering of rural residential areas around the urban central area. Therefore, it can be concluded that land use suitability, population density, and distance from urban areas are spatial-level driving at the spatial level that affect the change and development of rural population and residential areas.

Following preliminary processing of the mobile phone signalling data, a distribution map of social connection intensity is formed, which is superimposed with the suitability of the land use. It can be seen that the more suitable the land use conditions are for production, construction and living areas, the denser the particle distribution is (as shown in **Figure 4**).

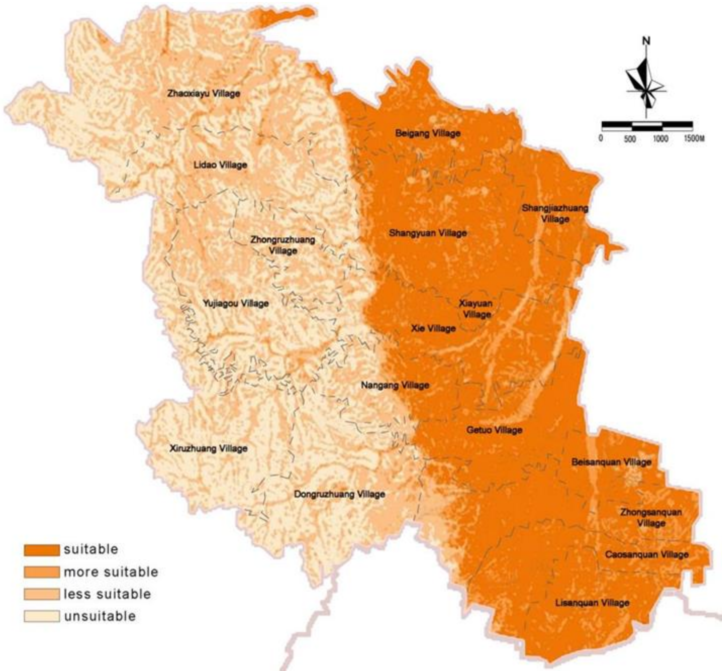

Figure 4. The relationship between particles distribution and land use suitability.

Subsequent to the initial processing of the signalling data, a distribution map of the strength of social ties is produced. This map is superimposed onto the densely populated areas of within the village. It can be seen that the areas with a higher number of permanent residents exhibit denser particle distribution (as shown in **Figure 5**). The data is then subjected to preliminarily processing to form a social connection intensity distribution map, which is superimposed on the generated distance map between the village and the urban area. The closer the area is to the urban area, the denser the particle distribution (see **Figure 6**).

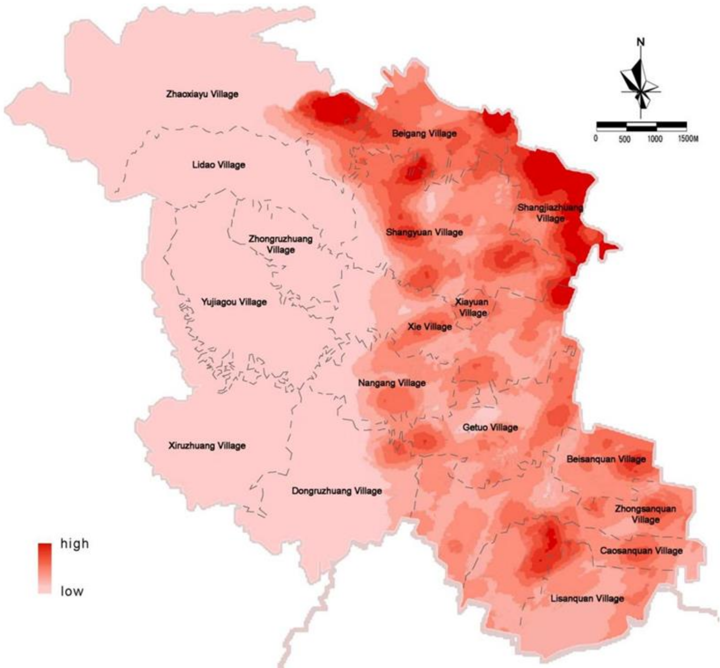

Figure 5. The relationship between particle distribution and population.

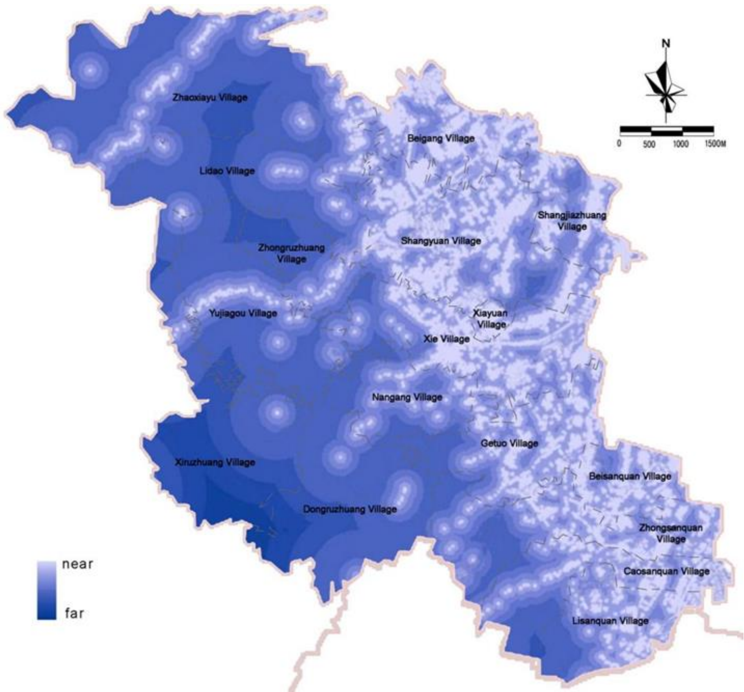

Figure 6. The relationship between particle distribution and distance from urban areas.

4.2. Layout update process

When implementing out Particle Swarm Optimization (PSO), the particles will progress towards the optimal solution until reaching the maximum iteration or threshold stop, through which the update speed and position of each particle can be determined. In the process of solving the village particle swarm optimization, it terminates after four iterations, that is, the final result of settlement optimization is obtained. Analysing the iterative results, the particles finally move to the villages in the northeast of the township. Many of these villages are positioned within the Pingchuan District, which is more suitable for agricultural production and rural construction. Furthermore, it is closer to the original Pingcheng District, with more convenient traffic conditions, and transportation infrastructure. This area is home to denser population and witnesses higher economic income in the rural area.

4.3. Result application

Rural development becomes increasingly reliant on the collaboration between urban and rural industries and the diffusion of urban functions. Guided by principles such as adaptation to local conditions, moderate scale, delivering favorable production, and bringing about favorable living conditions, starting from the actual situation in rural areas, promoting the moderate clustering and gradual migration of villages is particularly important for the efficient development of rural areas.

According to the particle swarm optimization results of Xiecun Township, the optimization and enhancement of the village residential areas are identified. There are three types of optimization particles formed in rural areas: dense optimization particles, sparse optimization particles, and no optimization particles. The optimization of particle cluster distribution reveals the different patterns within Xiecun Township. What shall be noticed is that, this phenomenon is not observed in township and urban areas bordering the area, mainly Xiecun Township, Shangyuan Village, Xiayuan Village, Xiecun Village, Beisanquan Village, Zhongsanquan Village, CaoSanquan Village. These villages boast good land use conditions and higher economic income, so they will be classified as cluster enhanced of the type of villages. Initial particle distance factor distribution of the densest region, while optimizing the particle population distribution of the densest region, and is located in the urban areas bordering the region, mainly Xiecun Township, Shangjiazhuang Village and Beigang Village. These two villages are closer to the central area of the city, which makes it possible to leverage city's financial and technological resources, improving the added value of agricultural products. As such, these villages will be classified as a peri-urban integrated type of villages. When it comes to the optimization of the sparse distribution of particle cluster area, mainly in Xiecun Township Ohtou Village, Nangang Village, Li Sanquan Village, these villages' land conditions, economic income are at average level, highlighting the need to cultivate rural advantageous industries and characteristic industries. Notably, it is of great importance to strengthen the urban and rural resources properly and systematically, which gives full play to the urban economic spillover effect of the promotion of rural development. In addition, it is imperative to boost the improvement of transportation conditions and the preservation of vernacular culture. This comprehensive approach helps realize the urban and rural regional economic green development and savvy development, classifying them as characteristic conservation villages. The villages lacking optimized particles mainly include Lidao Village, Zhongruzhuang Village, Chaoxiaoyu Village, Yujiagou Village, Xiruzhuang Village and Dongruzhuang Village in Xiecun Township, which should vigorously push forward the rational layout of the spatial organization of urban and rural settlements and pay more attention to the shaping of ecological space, as these villages will be classified as relocated and annexed villages. This designation accentuates the need to deliver overall development of the townships by the intensive land use.

5. Discussion

The village classification results for Xiecun Township, derived from the particle swarm optimization population flow model, provide more ideal insights into village development. Therefore, corresponding development strategies can be proposed accordingly to address the challenges associate real-life dilemmas (**Table 2**).

Table 2. Village development guidance under particle swarm optimization algorithm.

Model results	Village classification	Space optimization focus	Industry promotion focus
Optimizing the area with the densest distribution of particle swarms.	Cluster-enhanced villages.	Villagers are concentrated in communities, industries are concentrated in parks, and land is concentrated in large-scale operations.	Consolidate the industrial foundation and extend the industrial advantages.
The initial particle distance factor distribution is the densest area, while optimizing the particle swarm distribution of the densest area.	Peri-urban integrated villages.	Improvement of village style and traffic conditions.	Strengthen the function of undertaking and transferring urban industries.
Optimizing the sparse area of particle swarm distribution.	Characteristic conservation villages.	Village style improvement and historical and cultural protection.	Develop rural tourism and characteristic industries.
Area without optimized particle swarm distribution or extremely sparse area with optimized particle swarm distribution.	Relocation and annexed villages.	Ecological environment improvement and village relocation and resettlement work.	Improving the responsibility of village ecological protection and the task of increasing agricultural production and income.

5.1. Classification optimization space

Cluster enhanced type: Optimization is focused on areas where the distribution of particle swarms is most concentrated. This approach serves to promote the development of surrounding villages. Considering the characteristics of industrial layout and resource endowment, it coordinates the layout of villages, so as to guide villagers to concentrate in communities, industries in parks, and land in large-scale operations.

Peri-urban integrated type: The primary spatial constraint in this context is the distance factor. The initial particle distance factor is the most densely distributed area, and the area with the densest particle swarm distribution witnesses optimization at the same time. These villages are classified as urban-suburban fusion type, which is an essential area for urban-rural interconnection, co-construction and sharing. Also, attention is given to the improvement of village style and traffic conditions.

Characteristic conservation type: In this category, optimization of the areas where particle swarms are sparsely distributed. It emphasizes the selection areas with profound historical and cultural heritage and maintains intact village texture, classifies these villages as characteristic protection type. Also, attention is given to village style improvement and historical and cultural protection.

Relocated and annexed type: This encompasses areas without optimized particle swarm distribution or areas with optimized particle swarm distribution that are extremely sparse. These villages are classified as relocation and amalgamation type, focusing on ecological environment improvement and village relocation and resettlement.

5.2. Classification enhances the industry

According to the results of village layout reconstruction, industrial upgrading is conducted based on classification.

Cluster enhanced type: It is a key area for rural revitalization, entailing further consolidating the industrial foundation and extending industrial advantages. Efforts will be made to establish a multi-complex with perfect facilities, complete functions, beautiful environment, livable and suitable for business.

Peri-urban integrated type: This involves reinforcing the function of undertaking and transferring urban industries, gradually enhancing the ability to serve urban development, undertaking the spillover of urban functions, and meet the needs of urban consumption.

Characteristic conservation type: This includes maintaining the relationship between protection, utilization and development. Moreover, it involves tional utilization of village characteristic resources, developing rural tourism and characteristic industries, realizing the integration of primary, secondary and tertiary industries. What is more, a benign mutual promotion mechanism between characteristic resource protection and village development shall be delivered.

Relocated and annexed type: This classification involves reclamation or green initiatives according to local conditions. It concentrates on increasing the ecological space for rural production, and improving the responsibility of village ecological protection and the task of generating agricultural production and income.

5.3. Classified planning

Based on the results of village layout reconstruction, practical village planning is compiled in rural areas outside the urban development boundary, so as to truly realize the planning and unified management of both urban and rural areas. In line with the classification resulting from the optimization of village layouts, village planning is developed accordingly.

Cluster enhanced type: The planning primarily concentrates on the layout and control of land space, industrial development strategy, village residential area layout planning, rural life circle arrangement, infrastructure planning, living environment improvement planning and short-term construction plans.

Peri-urban integrated type: If the village is located within the boundary of urban development, a separate village plan is unnecessary. However, if it is not located within the boundary of urban development, the focus of planning is the layout and control of land space, infrastructure planning, improvement of living environments, and short-term construction planning.

Characteristic conservation type: The focus of planning is on historical and cultural protection and inheritance planning, disaster prevention and mitigation planning, guidance on the overall appearance of the village, and guidance concerning significant spatial refurbishments.

Relocated and annexed type: It is not necessary to prepare a separate village plan, but in other village planning, the situation of relocation, amalgamation and village resettlement should be considered as a whole.

6. Conclusion

In this study, we use cell phone signalling big data to develop a population flow model under particle swarm optimization algorithm. This model is based on the spatial driving forces and the strength of social ties, so as to determine the optimal scheme for the distribution of settlements. More importantly, it allows us to classify villages scientifically, and to propose the corresponding development strategies of villages according to the types of villages. Compared with other village classification schemes, the research method proposed in this paper relies on data and machine learning techniques, which avoids any subjective “human decision” and is more objective and implementable.

However, village classification a complex process affected by a combination of internal factors and external regulation, and it is a constructive means to promote integrated urban-rural development and rural revitalization by guiding and regulating the elements, structures and functions. In this paper, we have proposed a machine learning method for establishing establish the population flow model under the particle swarm optimization algorithm, aiming to classify villages in a creative and scientific manner. However, in the actual classification process of village types, it remains crucial to fully consult the farmers, especially in cases involving the relocation and annexation of villages. Such an approach should combine government guidance with villagers’ participation, and respect the will of the villagers as a prerequisite for the subsequent implementation of the operation. At the same time, village classification is not a static concept, and may witness changes due to the external conditions. Hence, it is necessary to dynamically adjust the classification of villages according to the actual situation at different points, and make adaptations in development strategy accordingly. By doing so, it will make certain contributions to the promotion of rural revitalization.

Author contributions: Conceptualization, XM, NU; methodology, XM; software, XM; validation, NU, NZ; formal analysis, XM; investigation, XM; resources, XM; data curation, NZ; writing—original draft preparation, XM; writing—review and editing, XM, NU, NZ; visualization, XM. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

References

Bogdanov N, Meredith D, Efstratoglou S (2008). A typology of rural areas in Serbia. Economic Annals 53(177): 7–29. doi: 10.2298/eka0877007b

Chen M, Gong Y, Lu D, Ye C. (2019). Build a people-oriented urbanization: China’s new-type urbanization dream and Anhui model. Land Use Policy 80: 1–9. doi: 10.1016/j.landusepol.2018.09.031

Christaller W (1966). Central Places in Southern Germany. Prentice-Hall.

Kennedy J, Eberhart R (1995). Particle Swarm Optimization. Proceedings of the Fourth IEEE Int. Conference on Neural Networks.

Li Y, Bu C, Cao Z (2020). Village classification system for rural vitalization strategy: Method and empirical study. Journal of Natural Resources 35(2): 243–256. doi: 10.31497/zrzyxb.20200201

Li Y, Yu K, Liang J, et al. (2022). A landscape-aware particle swarm optimization for parameter identification of photovoltaic models. Applied Soft Computing 131: 109793. doi: 10.1016/j.asoc.2022.109793

Li Z, Miao X, Wang M, et al. (2022). The classification and regulation of mountain villages in the context of rural revitalization—The example of Zhaotong, Yunnan Province. Sustainability 14(18): 11381. doi: 10.3390/su141811381

Liu S, Ge J, Bai M, et al. (2022). Toward classification-based sustainable revitalization: Assessing the vitality of traditional villages. Land Use Policy 116: 106060. doi: 10.1016/j.landusepol.2022.106060

Liu Y, Li Y (2017). Revitalize the world's countryside. Nature 548(7667): 275–277. doi: 10.1038/548275a

Ma L, Chen M, Fang F, Che X (2019). Research on the spatiotemporal variation of rural-urban transformation and its driving mechanisms in underdeveloped regions: Gansu Province in western China as an example. Sustainable Cities and Society 50: 101675. doi: 10.1016/j.scs.2019.101675

Molestina RC, Orozco MV, Sili M, Meiller A (2020). A methodology for creating typologies of rural territories in Ecuador. Social Sciences & Humanities Open 2(1): 100032. doi: 10.1016/j.ssaho.2020.100032

Raharja AB, Aji S, Syarifudin D (2020). Typology of the coastal countryside in supporting development of North coast region in West Java. Tataloka 22(4): 486–496. doi: 10.14710/tataloka.22.4.486-496

Sikorski D, Latocha A, Szmytkie R, et al. (2020). Functional changes in peripheral mountainous areas in east central Europe between 2004 and 2016 as an aspect of rural revival? Kłodzko County case study. Applied Geography 122: 102223. doi: 10.1016/j.apgeog.2020.102223

Tian Y, Qian J, Wang L (2021). Village classification in metropolitan suburbs from the perspective of urban-rural integration and improvement strategies: A case study of Wuhan, central China. Land Use Policy 111: 105748. doi: 10.1016/j.landusepol.2021.105748

van Eupen M, Metzger MJ, Pérez-Soba M, et al. (2012). A rural typology for strategic European policies. Land Use Policy 29(3): 473–482. doi: 10.1016/j.landusepol.2011.07.007

Xu Y, Hu C, Wu Q, et al. (2022). Research on particle swarm optimization in LSTM neural networks for rainfall-runoff simulation. Journal of Hydrology 608: 127553. doi: 10.1016/j.jhydrol.2022.127553

Ye C, Liu Z (2020). Rural-urban co-governance: Multi-scale practice. Science Bulletin 65(10): 778–780. doi: 10.1016/j.scib.2020.02.021