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Assessment of Social-Economic Risk of Chinese Dual Land Use System Using Fuzzy AHP

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Abstract: The Chinese dual land use system (DLUS) has played a crucial role in the industrialization of China since 1950s. However, this dual system caused/causes obstacles in urban development under the new market economic conditions. This paper presents an approach to assess the social-economic risks during urban development in China by integrating the strategic environment assessment (SEA) principle into the fuzzy analytic hierarchy process (AHP) method. In the proposed approach, SEA principles are set as the influencing factors in AHP. Fuzzy AHP is used to assess the relative importance degree of the six principles in SEA. To illustrate the application procedure of the proposed approach, a building collapse incident in Wenzhou is used as a case for the risk analysis. The assessment results show that the index of the manage system has the greatest importance to social-economic risk. The principle of sustainable development (A) and monitoring measures (E) have more importance than the other principles in SEA. It can be concluded that the DLUS in the market management of China may be responsible for building collapse incidents in rural areas. It is suggested that the principles of sustainable development and monitoring measures in SEA should be strictly implemented during urbanization, and it is recommended that the government establish a unified management system and ensure the effective implementation of sustainable urbanization.

Keywords: dual land use system; social-economic risk; fuzzy AHP; Strategic Environmental Assessment (SEA); unified management system

1. Introduction

Since the 1950s, China has conducted a land ownership reform in which land ownership was separated into two categories under the land reallocation system: ownership by the country's population (state-owned urban land) and collective ownership by the working people in a working group (collective-owned rural land) [1,2]. The first category was managed at a national level (usually in urban areas), while the second category was managed within rural areas. Land was owned by the country and small working groups, which formed the so-called urban-rural dual social structure. The dual structure separated the urban and rural areas and restricted land market access. In the urban areas, all land was tightly managed by the government and allocated rent-fee to tenants. In the rural areas, some of the land was managed by rural residents themselves, to which the government did not provide enough management. This system is called the dual land use system (DLUS) in this paper. This land management system sped up the industrialization of China from 1950 to the end of the 1980s.

However, the DLUS became inefficient and unsustainable, considering the increasing demand for urban land since the 1990s with the development of market economy conditions.

With the rapid economic development since the 1990s in China, human activities gradually became significant factors in affecting the environment and inducing various hazards. Rapid urbanization stimulates the construction of roads, bridges, and underground transit networks [3–8], as well as the development of residential areas. In rural areas, many aged residential buildings were constructed with unauthorized rooftop additions. Urbanization and economic migration of workers from rural to urban areas has changed the natural and residential conditions. Thus, the migration of workers leads to an increase in natural and man-made hazards [9–14]. These hazards include building collapses, flooding, land subsidence, water pollution, soil pollution, and slope failures [15,16]. When the factors causing hazards due to human activity are not carefully controlled, catastrophic failures often occur, which has a great impact on the environment and public health.

Strategic Environmental Assessment (SEA) is an effective tool to evaluate the environmental impact of human activity to keep urban development sustainable [14,17]. SEA considers the principles of environmental impact assessment in urban planning and decision-making policy for sustainable development [18,19]. SEA has been adopted by numerous countries to enhance sustainability of development. During the implementation of SEA, different countries should consider their specific circumstances and characteristics. In China, the implementation of SEA should take different ways to achieve sustainable development. It is important to make a social-economic risk assessment for sustainable urban planning.

There are many risk assessment methods, including the analytic hierarchy process (AHP) [20], fuzzy AHP [21,22], the analytic network process (ANP) [23], and gray theory [24]. Fuzzy AHP is an effective approach to deal with uncertain, ambiguous, or imprecise data. Fuzzy AHP can also manage the complexity of assessment systems. This paper employs the method of fuzzy AHP to evaluate social-economic risk integrated with the SEA. The objectives of this paper are (i) to assess the social-economic risk of the dual land use system (DLUS) under market economic conditions and (ii) to propose recommendations for unified management regulation to mitigate the environmental risks of DLUS for the sustainable development of rural areas.

2. The Dual Land Use System

2.1. Household Registration System in China

Since the late 1950s, a dual structure system between residents of urban and rural areas gradually formed in China. Each resident has a household registration in this dual structure system, which caused a dichotomy between rural and urban residents. Urban registration residents have advantages such as working in a certain industry. Moreover, there were also differences in the household system between the rural and urban residents. Housing for urban residents was constructed and distributed by the government. Housing for rural residents was constructed with properties for residents themselves on their own rural homestead land under collective ownership. In most situations, the benefits for urban residents were greater than those for rural residents before the 1990s. In many cases, rural residents tried to claim urban residency status. To standardize the status of the household registration system, in 1988, the Chinese Government first announced a "dual structure" policy to separate rural and urban residents into two distinct groups. However, there were three main drawbacks raised after announcing this policy, including (i) curbing economic migration of workers from rural to urban areas, (ii) restrictions on urbanization, and (iii) an increased dichotomy between rural and urban areas [25,26]. The "dual structure" policy distinguished rural resident households from city resident households, restricting population migration to the urban cities [27,28].

However, there were some benefits for rural residents. For example, rural residents won the right to construct houses or buildings on their own rural homestead land without government approval. In the DLUS, when building is conducted in urban areas, the procedure for design and approval should be strictly followed. However, for buildings in rural areas, since the investment came generally from rural residents themselves, the procedure for design and approval was generally not strictly required. Since the 1990s, with the economic boom in China, many factories have been constructed in rural areas, e.g., in coastal regions such as Wenzhou, which encouraged the migration of workers from inland rural areas to coastal rural areas. This population migration provided opportunities for the coastal rural residents to lease their houses to these new migrants from inland provinces. As a result, there are more and more buildings with rooftop additions to meet the demand from new migrants.

2.2. DLUS-Induced Problems

The dual land management system has played a vital role in China's economic activities. Due to large-scale industrialization, urban land consumption far exceeded expectations and exceeded the total urban land area available. From 2000 to 2010, the urban population increased by 46%, and built-up areas increased by 65%. The rate of urbanization in China increased from 36% in 2000 to 54% in 2013 [29,30]. Accordingly, each one percentage point increase in the rate of urbanization will require 670,000 hectares of extremely limited urban land [1]. To meet the short supply of urban land, city governments began to carry out land acquisition of rural lands. During the land acquisition process, the government acquired rural land for prices far below market rates. However, since the 1980s, according to new land policy, this rural land can be sold only at higher prices than market rates. Due to a lack of reasonable compensation for the acquisition of rural land, rural residents usually do not have any intention of allowing the government to acquire rural land but would instead build residential buildings on their own land. In addition, many residential buildings were developed for lease or sale on these lands, increasing the transaction potential of rural land, particularly in coastal cities.

Thus, under the DLUS, since there is not enough government supervision of construction in rural areas, the quality of buildings constructed by the rural residents is poor. There have been more than 13 collapse incidents from 2009 to 2017 [31,32]. As illustrated by Lyu et al. (2018) [31], the incident locations were mainly located in the coastal area of China. In the past three decades, the coastal area has experienced rapid development. The rural areas have been gradually surrounded by urban areas, which leads to the appearance of "urban villages" (urban area is surrounded by rural area). These collapsed buildings mostly happened in these "urban villages." Most of the collapsed buildings with rooftop additions were constructed by residents themselves. The construction of the illegal rooftop additions is ascribed to a lack of strict management because of the rural land use policy.

3. Methodology

3.1. Analytic Hierarchy Process

AHP was originally proposed by Saaty [19–21]. AHP can evaluate the results both qualitatively and quantitatively. To reflect the influence of each factor, the AHP model is characterized of the object layer, ruler layer, and factor layer. The main steps of AHP are as follows: (1) establishing analytic hierarchy model on the basis of relative factors, (2) establishing assessment matrix with Equation (1), (3) calculating weight coefficients of each factor as shown in Equation (A1) in Appendix A, (4) validating consistency ratio ($CR < 0.1$) of the judgment matrix by Equation (A2) in Appendix A, and (5) calculating comprehensive weight coefficient of each factor.

$$A_u = (a_{ij})_{n\times n} = \begin{pmatrix} 1 & \cdots & a_{1n} \\ \vdots & 1 & \vdots \\ \frac{1}{a_{1n}} & \cdots & 1 \end{pmatrix} \tag{1}$$

where A_u is the judgment matrix, and a_{ij} is the relative value of i factor to j factor, which is range from 1 to 9 and their reciprocals. Based on the judgment matrix, the weight of each factor can be calculated. According to Saaty [19–21], if the value of consistent ratio (CR) is less than 0.1, the judgment matrix is reasonable; if the value of CR is greater than 0.1, then the judgment matrix is unreasonable and must be re-determined. The detailed calculation process of the weight and CR is listed in the Appendix A.

3.2. Fuzzy AHP

Fuzzy AHP theory uses approximate information and uncertainty of human reasoning to generate decisions. Vagueness is always encountered in decision making. Good decision-making models should be able to consider the vagueness of factor. A fuzzy set model is characterized by an objected feature matrix as shown in Equation (2). To consider the relative membership degree of judgment factors, the objected feature matrix should be transformed as relative membership degree matrix as shown in Equation (3).

$$B_p = (b_{ij}) = \begin{pmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{m1} & b_{m2} & \cdots & b_{mn} \end{pmatrix}_p \tag{2}$$

where B_p is the objected feature matrix, and b_{ij} is the score of j plan to i factor, which is according to the score by an expert.

$$R_p = (r_{ij}) = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix}_p \tag{3}$$

where R_p is the relative membership degree matrix and r_{ij} is the relative membership degree of j plan to i factor. r_{ij} can be calculated according to Equations (A3) and (A4) in the Appendix A.

Based on the combination of the weight coefficients calculated by the AHP and the relative membership degree matrix, a fuzzy optimization decision model is established using Equation (4).

$$u_j = \frac{1}{1 + \left(\frac{1}{\sum_{i=1}^{m} w_i r_{ij}} - 1\right)^2} \tag{4}$$

where u_j is the relative membership degree, w_i is the weight coefficient calculated by the AHP, r_{ij} is the relative membership degree based on the fuzzy theory.

3.3. SEA Principles

SEA evaluates the environmental impacts of policies, plans, and program. This approach can effectively weave sustainability principles into fabric of urban plans. The SEA concept was first proposed by Shepherd and Ortolano (1996) [23] for sustainable urban development. The SEA includes six principles, which are (A) considering sustainability principle systematically, (B) evaluating projected environmental impacts related to policy plans and construction, (C) considering cumulative and correlated impacts, (D) tiering to consider sustainability principles from policies, plans and programs (PPPs) to projects, (E) monitoring and adopting measures to improve environmental management, and (F) perfecting legal and public monitoring mechanisms. Several research projects report that SEA can qualitatively evaluate environment risk more comprehensively than other methods [14,32–34]. SEA can incorporate sustainability principles throughout decision making from policies, plans, and programs to the level of projects. The decision making in the SEA is based on the experts' score for each principle from (A) to (F). This cannot consider the relative degree of importance among different principles. This study integrates SEA principles into fuzzy AHP to assess the relative degree of importance among different principles.

4. Case Analyses with the Proposed Method

The above approach is used to analyze a building collapse incident in Wenzhou City. On 10 October 2016, a severe building collapse incident happened in Wenzhou City, China, which caused 22 deaths and six injuries. Most victims were migrant workers, and this remains a painful lesson for the Chinese Government when considering future reform of land policy. Figure 1 shows the situation at the collapsed site. The group of residential buildings was surrounded by high-rise buildings (see Figure 1a). The collapsed buildings were surcharged with unauthorized rooftop additions (see Figure 1b). Wenzhou City lies on the southeast coast of Zhejiang Province and is underlain by plastic marine clay deposits. Figure 2 shows the topography of Wenzhou City. Based on site investigations, the average elevation of Wenzhou City is 450 m. There are abundant soft marine clay deposits present in regions at low elevation. Figure 3 shows the topography of Lucheng District. As shown in Figure 3, the collapse site is located on a floodplain and is close to the confluence of inland rivers (see Figure 2). The geotechnical conditions require foundation treatment at the locations of the collapse site [35–43], which unfortunately was not carried out.

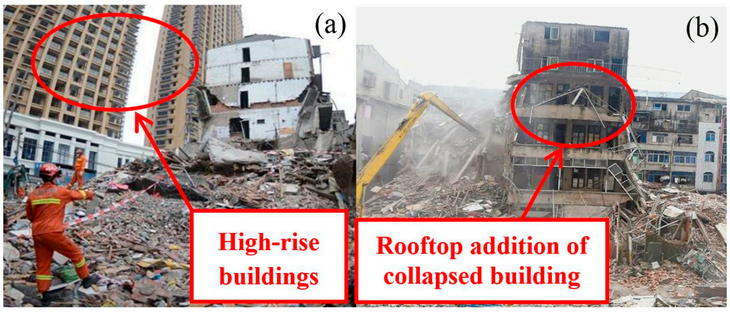

Figure 1. Photos of the four collapsed residential buildings: (**a**) high-rise buildings in the vicinity of the site; (**b**) an illegal rooftop addition.

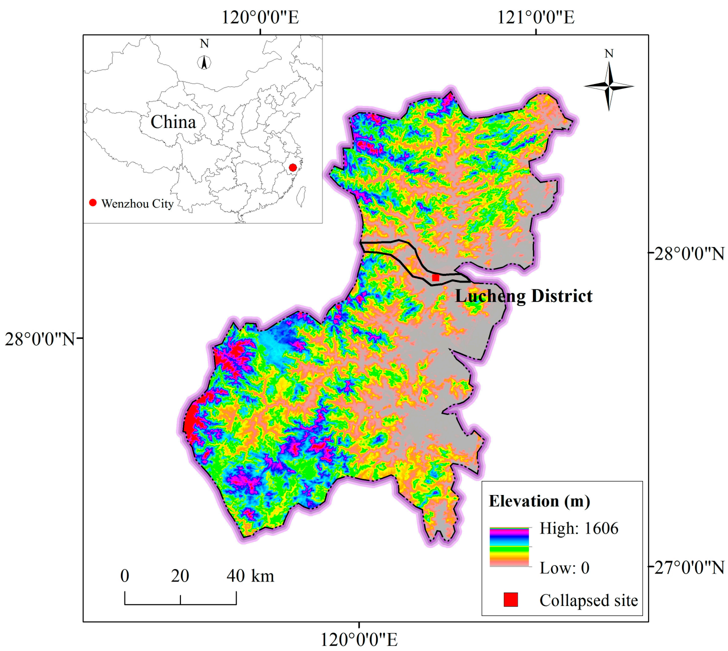

Figure 2. Topography of Wenzhou City.

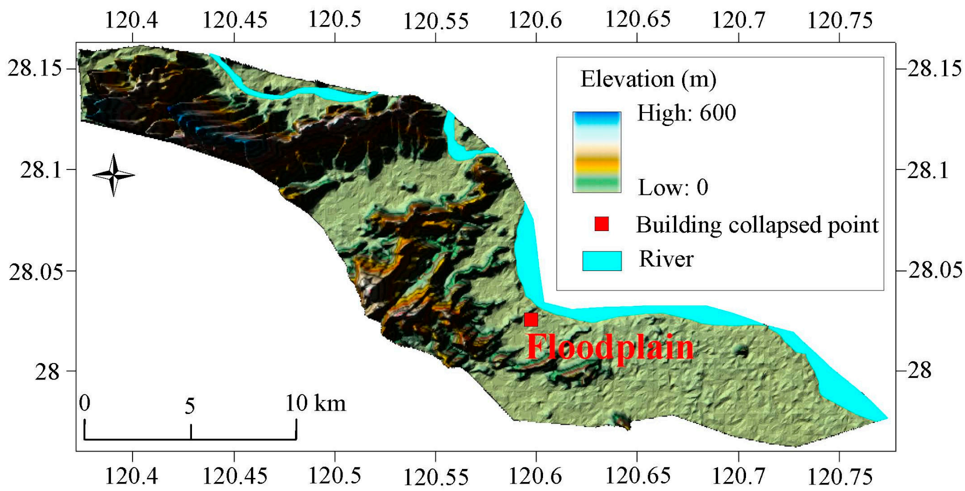

Figure 3. Topography of Lucheng District.

Figure 4 shows the schematic illustration of the collapsed residential buildings. Based on the preliminary investigations, the two-story building had one unauthorized rooftop addition, while each of the six-story buildings had two unauthorized rooftop additions. These unauthorized rooftop additions made a significant contribution to this collapse incident. The underlying marine clay has very low shear strength and is not capable of providing adequate bearing resistance to support buildings or structures. In addition, there were additional high-rise buildings around the collapsed buildings. Differential settlement (δ) was observed at the collapse site [44–47] and further developed through continuous consolidation resulting from the creep effect [48,49]. Generally, during the construction of any building with more than two floors, ground improvements need to be conducted using techniques such as prefabricated vertical drain and jet-grouting [50–52]. Both the effects of unauthorized rooftop additions and the surrounding high-rise buildings contributed to the collapse of the residential buildings.

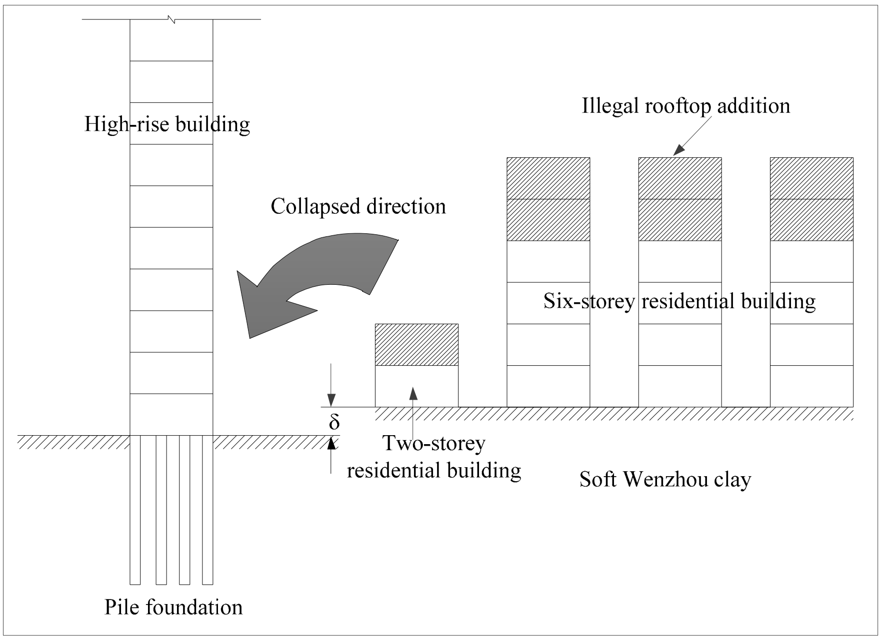

Figure 4. Schematic illustrations of the residential buildings in this collapse incident.

5. Risk Assessment

5.1. AHP Structure

To assess social-economic risk during urbanization, the conceptual assessment model was established based on the investigation of collapse incidents and social backgrounds. Figure 5 shows the AHP structure for social-economic risk assessment. The established structure was characterized by the technological level (U_1), dual social system (U_2), and management system (U_3). First, these self-conditions of collapsed buildings were considered from the technology level. Second, the external factors induced by social background were considered from the perspective of a dual social system. Third, the management system was implemented for sustainable development. This model was established based on the AHP theory. The SEA principles for social background and management system were considered as influencing factors in the fuzzy AHP model.

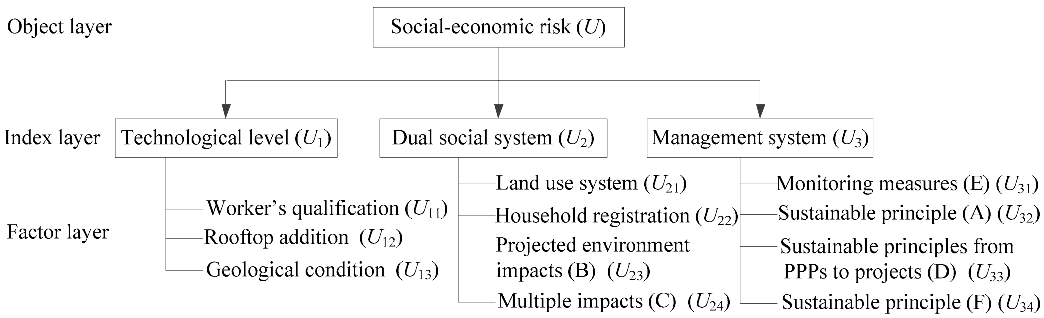

Figure 5. Analytic hierarchy process (AHP) structure for social-economic risk assessment.

5.2. Weight Calculation

To assess the social-economical risk of the environment on the basis of the hierarchy structure (see Figure 5), the judgment matrix of each factor was established. The relative importance of two elements was rated using the nine-scale method. The judgment matrix of index layer (U_i) to object layer (U) can be established according to the AHP method by Saaty [19–21]. Similarly, the judgment matrix of factor layer to index layer can also be established. The weight coefficient of each factor can be obtained using Equation (2). Figure 6 shows the comprehensive weight coefficient of each factor in the assessment model.

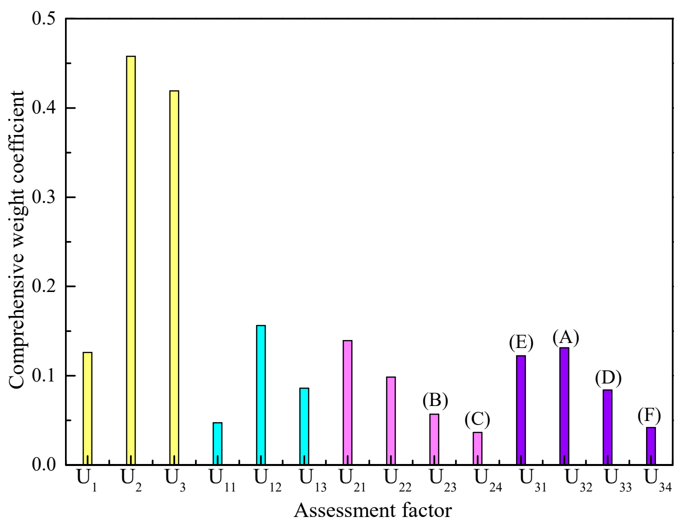

Figure 6. Comprehensive weight coefficients of assessment factors.

5.3. Fuzzy AHP Method

To assess the relative degree of importance of six principles in the SEA, a questionnaire of experts with six principles from the perspectives of technology level, dual social system and management system was conducted to determine the criteria for evaluation. We have consulted 15 experts. Then, according to experts' scores, we determined the score of each principle in the SEA. It is worth to note that, the scores are ranged from a low value to a high value, but we determined a mean value to evaluate its influence. This mean value was used to guarantee the next calculation. Table 1 tabulates the scores of six principles in the SEA. Based on the scores as listed in Table 1, the fuzzy judgment matrix X can be obtained as Equation (4). Applying Equation (A3) or Equation (A4) in the Appendix A, the relative membership degree matrix R can be obtained (here, we use Equation (A3)).

$$X = \begin{pmatrix} 5 & 3 & 4 & 6 & 6 & 5 \\ 7 & 8 & 3 & 4 & 3 & 3 \\ 9 & 7 & 4 & 5 & 9 & 8 \end{pmatrix} \quad R = \begin{pmatrix} 0.6667 & 0 & 0.3333 & 1 & 1 & 0.6667 \\ 0.8 & 1 & 0 & 0.2 & 0 & 0 \\ 1 & 0.6 & 0 & 0.2 & 1 & 0.8 \end{pmatrix} \tag{5}$$

Table 1. Scores of six principles based on experts.

SEA	Index (Score Out of 10)		
	Technology Level	**Dual Social System**	**Management System**
A (U_{32})	5	7	9
B (U_{23})	3	8	7
C (U_{24})	4	3	4
D (U_{33})	6	4	5
E (U_{31})	6	3	9
F (U_{34})	5	3	8

5.4. Assessment Results

According to the results in Figure 6, we can find that the index of the management system plays the most important role in the social-economic risk. The result shows that, from the perspective of the technology level, the factor of rooftop addition was the greatest factor that induced this collapse incident, and the second factor was the geotechnical conditions (soft clay deposits). From the perspective of the dual social system, the factor of the land use system was the greatest risk, followed by the household registration system. From the perspective of the management system, there were four factors of the SEA: (A), (E), (D), and (F) which were relatively higher than the other factors. The results reveal that the poor quality of structures of the collapsed buildings that induced this collapsed incident had significant impacts. To mitigate the risk to the environment, it is recommended that the principle of sustainable development (A) and monitoring measures (E) in the SEA should be strictly implemented in future. This implies that in the future the dual management systems for DLUS should be combined to make a unified management system.

The weight coefficients of six factors of the SEA are as follows:

$$w_i = [(A), (B), (C), (D), (E), (F)] = [0.1313, 0.0569, 0.0364, 0.0839, 0.1222, 0.0420]. \tag{6}$$

According to the weight coefficients w_i and the fuzzy judgment matrix R, the optimized relative membership degree u_j can be calculated by using Equation (A1) in Appendix A.

$$u_i = [0.1866, 0.0099, 0.0002, 0.0174, 0.0947, 0.0043] \tag{7}$$

Figure 7 shows the rank of the relative membership degree for six principles in the SEA. As shown in Figure 7, the principle of sustainable development (A) was the most significant factor, followed by the principle of monitoring measure (E). The results reveal that, the principles of sustainable development and monitoring measures have critical impacts in the process of urban development. The Wenzhou government should pay more attention to these two factors to mitigate social-economic risk in the future.

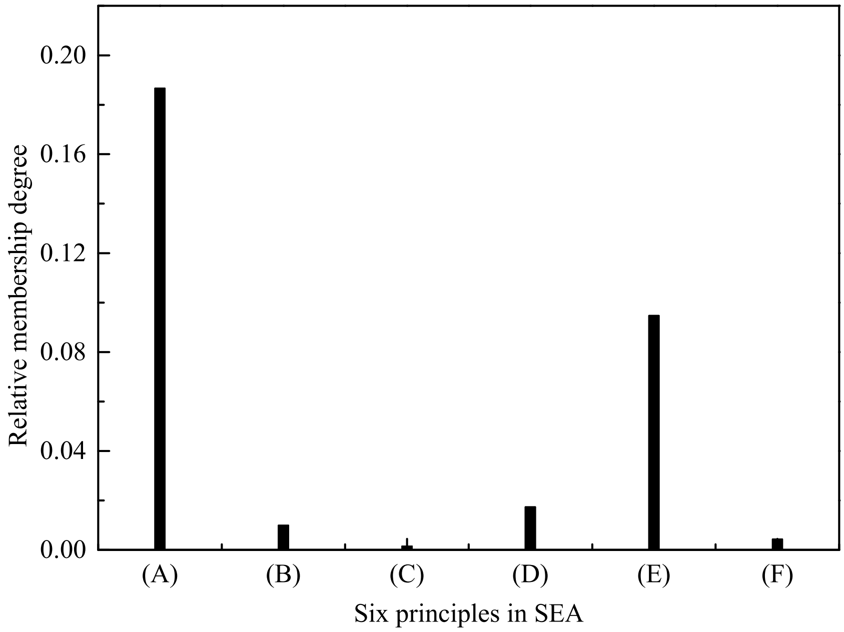

Figure 7. Rank of the relative membership degree for six principles in strategic environment assessment (SEA).

6. Discussion

6.1. Implications

The application of fuzzy AHP integrated with SEA principles was conducted to evaluate the social-economic risk during urban development. An assessment index system with three indices and 11 sub-indices was established for social-economic risks. The AHP method was adopted to determine the weight coefficients of factors, and the fuzzy theory was applied to evaluate the relative importance of each principle in the SEA. Subsequently, the comprehensive fuzzy AHP model was used to assess the social-economic risks to the environment. Fuzzy AHP can combine qualitative and quantitative analyses in risk assessment. The integration of fuzzy AHP and SEA can give a comprehensive assessment of social-economic risk in urban development. In comparison with SEA, using AHP can quantitatively evaluate the effective degree among SEA principles, which provides decision makers with a quantitative judgment. According to the assessment results, the management system is the most important factor in urban development. For the six principles in SEA, the factors of sustainable development (A) and monitoring measures (E) are more important than other principles. The social-economic risk assessment results provided an indication of the relative importance of the various factors for urban development. During urban development, many social and environmental problems appeared relevant to the DLUS. For social issues, e.g., collapse incidents in the rural area surrounded by urban areas, the poorly built structure of the collapsed building was the main reason for the incident, which was due to poor management under the DLUS. According to the statistical result by Lyu et al. (2018) [31], there were more than 12 collapse incidents from 2009 to 2016 [31]. To mitigate the risk of future similar incidents, it is recommended that the principles of SEA should be implemented, particularly for the principles of sustainable development (A) and monitoring measures (E). Based on the evaluated results, the government and local authorities should establish a unified management system for both urban and rural regions to mitigate social-economical risk and to keep urban development sustainable.

6.2. Suggestions

During the past four decades, Chinese reform has achieved much success. Land use reform is the inevitable trend in urban development. However, there are many social issues that have arisen during the urbanization process [53,54]. Environmental and social issues caused by the DLUS have promoted the integration of policies between urban and rural area. Figure 8 shows the social-economic relationship as well as reform countermeasure for land-policy to sustainable development. Many environmental and social issues appeared during the process of urbanization demand for sustainable countermeasures. Therefore, in the land-policy reform process, local governments and authorities should pay more attention to establishment of the unified management system. The unified management system means that the urban and rural should obey the same management regulation or law. During renovations in the rural area surround by urban area, the authorities should strengthen the management measures. It is challenging to achieve unifying management between urban and rural areas. The assessment of social-economic risk gives a suggestion for authorities to identify the influencing factors. According to the assessed result of social-economic risk, the principles of sustainable development and monitoring measures in SEA should be emphasized. In addition, the government should accelerate the process of land-policy reform to mitigate social issues and strengthen the regulations on construction (such as banning of illegal rooftop additions and building on untreated soft clay).

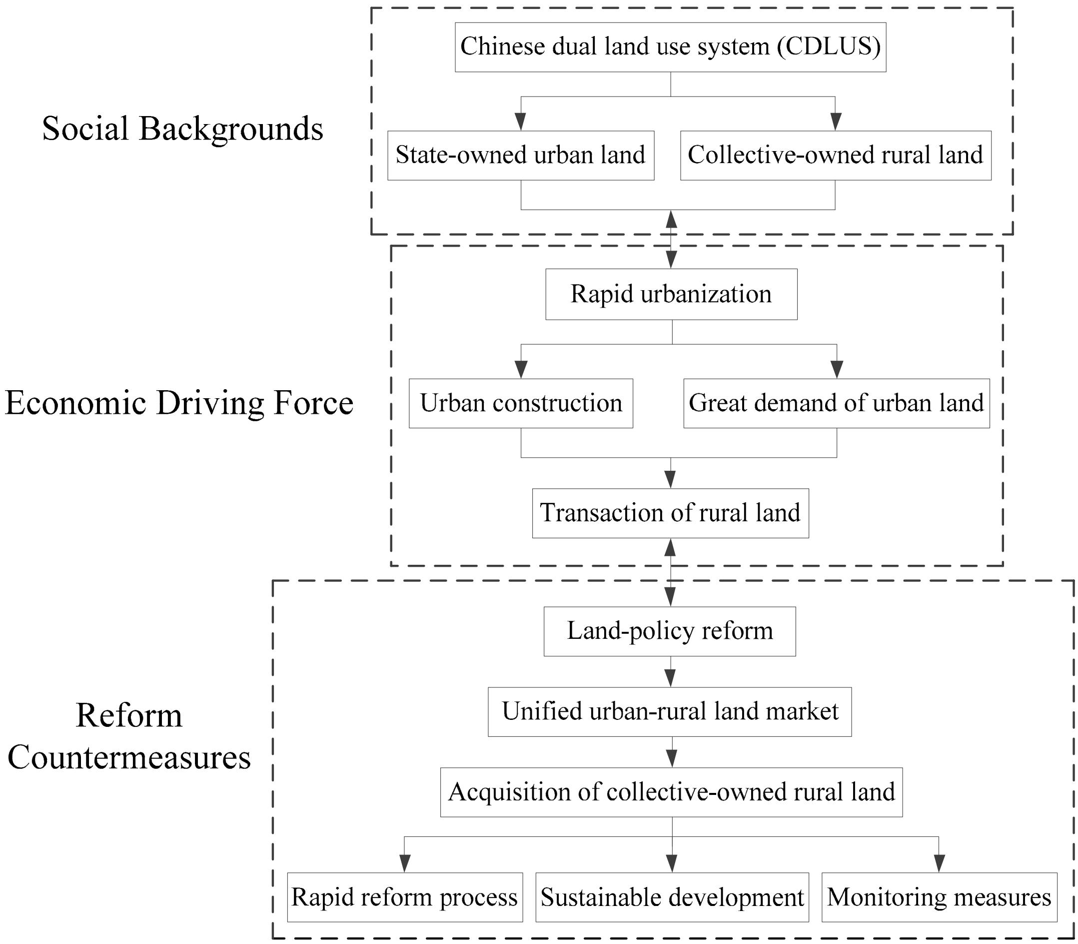

Figure 8. Framework of social-economic relationship and reform countermeasures.

7. Conclusions

This paper applied the fuzzy AHP method integrated with SEA principles to assess the social-economic risk of the Chinese dual land use system. A collapse incident in Wenzhou was used as an example to illustrate the application procedure. According to the analysis, the following conclusions can be drawn.

1. The assessment structure for social-economic risk was established with three indices and 11 sub-indices. The SEA principle was considered as sub-indices in the assessment structure. The AHP method is used to calculate the weights of assessment factors, while fuzzy AHP is used to assess the relative importance degree of the SEA principles. The integration of fuzzy AHP and SEA principles can give a qualitative assessment for social-economic risk in urban development.
2. Assessment results show that the management system is the most important factor in urban development. For the six principles in SEA, the optimized relative importance degrees of the factors of sustainable development (A) and monitoring measures (E) are greater than other principles. Therefore, the principles of sustainable development and monitoring measures in SEA should be strictly implemented during urban development.
3. In the future, it is recommended that the government establish a unified management system for both urban and rural areas that can ensure the effective implementation of sustainable urban development. The supervision capacity of government authorities to prevent unauthorized rooftop additions also needs to be strengthened. Mandatory regulations for construction projects in China, particularly for private self-constructed work undertaken on house-building sites in rural areas, should be strictly carried out.

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Appendix A. Supplement for the Calibration Formula in Context

1. The weight of assessment factor in the judgment matrix can be calculated using Equation (A1).

$$w_i = \frac{M_i}{\sum\limits_{i=1}^{n} M_i} \tag{A1}$$

where w_i is the weight coefficient of each factor; $M_i = \sqrt[n]{\prod\limits_{j=1}^{n} a_{ij}}$.

2. The value of CR can be calculated using Equation (A2).

$$CR = \frac{CI}{RI} = \frac{\sum\limits_{j=1}^{n} a_j CI_j}{\sum\limits_{j=1}^{n} a_j CR_j} \tag{A2}$$

where $CI = (\lambda_{\max} - n)/(n-1)$; $\lambda_{\max}$ is the largest eigenvalue of judgment matrix; n is the dimension of the judgment matrix.

3. The normalized formula is as follows:

$$r_{ij} = \frac{b_{ij} - \hat{j} b_{ij}}{\overset{\vee}{j} b_{ij} - \hat{j} b_{ij}} \tag{A3}$$

$$r_{ij} = \frac{\overset{\vee}{j} b_{ij} - b_{ij}}{\overset{\vee}{j} b_{ij} - \hat{j} b_{ij}} \tag{A4}$$

where b_{ij} is the score of j plan to i factor and $\wedge$ and $\vee$ are represent the minimum and maximum, respectively.

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