Hindawi
Mathematical Problems in Engineering
Volume 2022, Article ID 7339005, 8 pages
https://doi.org/10.1155/2022/7339005

Research Article

The Coupling Relationship between Urban Resilience Level and Urbanization Level in Hefei

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Received 29 October 2021; Revised 6 December 2021; Accepted 28 December 2021; Published 21 January 2022

Academic Editor: Xunjie Gou

Urban resilience and urbanization have been researched wildly by urban researchers. The coupling relationship between the level of urban resilience and urbanization is a considerable reference to assess the quality of urban development. Based on the correlation of objective index data, it theoretically explains whether the urban resilience level is coupled with the urbanization level and the degree of coupling, providing advice and wisdom for the future high-quality urban development of Hefei. *Objective*. To explore whether there is coupling between the urbanization level and the urban resilience level and to explore what extent of the coupling is. *Research Methods*. The dimensionless method was mainly used to standardize the original statistical data, the entropy method can be chosen to obtain the weight of the indexes of urbanization level and urban resilience level, and the coupling coordination model was chosen to study the degree of coupling coordination. *Research conclusions*. From 2011 to 2013, the coupling coordinate on degree was low. The coupling coordination level of urbanization and urban resilience was moderately unbalanced in 2011, mild disorder in 2012, and primary coordination in 2013. However, in 2014 and 2015, the situation improved a lot, and the coordination degree was intermediate coordination. From 2016 to 2019, the coupling coordination degree was in the stage of advanced coordination.

1. Introduction

In March 2019, the Ministry of Housing and Urban-Rural Development issued the notice on organizing and recommending the first batch of cities to carry out physical examination evaluation, and then, the relevant places carried out an urban physical examination in an orderly manner. Among them, the city's safety resilience, as an important indicator, is subdivided into several sublevel indicators. Thus, the level of urban resilience is an important topic of concern to researchers and city managers in the field of urban planning. Especially in latest several years, the process of urbanization has been rapidly promoted in China which manifests in the urbanization rate having been continuously improved, the population having been rapidly expanding, and economic activities becoming more intense. It also leads to difficulty in maintaining a stable dynamic balance within the city. At present, socialism with Chinese characteristics has entered a new era, which is reflected in the field of urban work in that the people's pursuit of a better life is the foothold of urban work. Strengthening urban resilience is a way to solve the most direct and realistic problems that people are most concerned about in the field of urban planning. Urban resilience theory provides the system framework to solve the city security risks [1], which strengthens the ability to resist disasters. If urbanization can properly absorb urban resilience theory, there will be a long-term practical significance to achieve high-quality development, to build a resilient city, to solve the problem of city disease, and to enhance the ability of cities against disaster.

Resilience usually can be understood as a meaning of "the ability to return to an initial state" [2]. Urban resilience could be against severe shock so that the urban system still maintains stability in structure and functions [3]. Holling applied the concept of resilience at the first time in the field of systems ecology [4]. Resilience thinking is a kind of capacity that can be understood as a system to absorb uncertain disturbances and to maintain its own structures and processes [5]. With the deepening of relevant research, foreign studies on urban resilience become more and more sufficient. Many scholars put forward their own viewpoint. For example, a

system's resilience features should be evaluated in a wider perspective [5, 6]; resilience was a method to deal with urban problems [7]; resilience was an ability of the system to absorb kinds of disturbances and acquire a balance by its own recovery [5, 8]; resilience was a capacity which can absorb external pressures or uncertain and destructive forces by adaptation to the changes [9], and resilience allowed a system to adapt to changes [10, 11].

In the field of urban research abroad, the application of urban resilience theory has been greatly favored because it can be applied to many urban risk problems and other uncertain urban problems [12, 13]. In urban planning, the principles of resilience thinking were argued that it contributed a lot to the emergence of a sustainable urban system [14]. The theory of urban resilience has considerably been accepted, absorbed, and used for reference by many foreign cities and organizations to deal with urban problems. At the same time, foreign researchers have found ways to assess the resilience of cities, mainly using quantitative methods, such as models or an index system [15]. They focused on social, ecological, and environmental factors [16]. In general, foreign research on urban resilience has formed a relatively complete theoretical system on urban resilience, from the concept of resilience to the measurement method of resilience level and the implementation strategy of resilience theory. Due to the intersecting of related research fields and contents, the field of urban planning gradually absorbed the idea of resilience, which laid a theoretical foundation for the formation and development of urban resilience. At present, domestic studies on urban resilience are no longer limited to the identification of the concept of urban resilience, the measurement of the resilience level and the theoretical framework of resilient cities [17], but have diverged. For example, Dalian's urban resilience was evaluated based on "scale-density-morphology" [18]. In addition, other scholars in this field have also studied the coupling relationship between urbanization and urban resilience. For example, Wang et al. have studied the coupling relationship between the urbanization level of the Pearl River Delta and the ecological resilience of various cities in the region [17]. Some scholars have also studied the urban resilience of Harbin-Changchun urban agglomeration [19], and some scholars have conducted a comparative study on the urban resilience of agglomerations in China [20]. However, few scholars studied the relationship between the urban resilience of a single city and its urbanization level. Based on these previous research studies, Hefei was taken as an example to explore this kind of relationship from the perspective of coupling coordination. The geographical location of Hefei is shown in Figure 1, and the administrative area is shown in Figure 2.

The speed of development of Hefei is remarkable in recent years, according to the statistical data in 2020. Its GDP exceeded 1 trillion Yuan, and its urbanization level is ahead of other cities in the province of Anhui. But with its rapid development at the same time, many urban problems are also exposed. From the perspective of the urban resilience level alone, it seems that it is not coordinated with its urbanization level. Therefore, this paper discusses the relationship between the urbanization level and urban resilience level in Hefei and

Figure 1: Location of Hefei in Anhui Province.

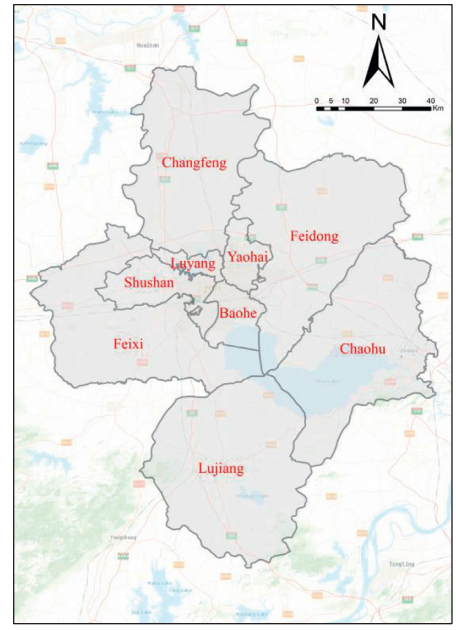

Figure 2: Zoning map of Hefei.

demonstrates the coupling coordination relationship between them, expecting to contribute wisdom to the high-quality urban development of Hefei.

The remaining part of this paper is structured in the following manner: Section 2 is devoted for the theoretical mechanism that urbanization and urban resilience restrict and promote each other; Section 3 expounds the sources and processing methods of the data used in this paper and how to build the evaluation index system of the research object; Section 4 shows the results calculated according to various indicators; and in Section 5, according to the research results, some strategies to enhance the level of urban resilience are put

forward, and the future research direction is pointed out. In Figure 3, we can see the flow of this research.

2. Theoretical Mechanism

City is a complex and huge social system, with strong material input and output, energy exchange, and other activities. Urbanization is a stage that urban development must go through, and it is mainly reflected in the urbanization of the population, economy, society, space, and residents' way of life. Urban problems will inevitably appear in the process of urbanization. How to solve these problems of urban development is a concern to many urban researchers which results in the theory of urban resilience being introduced and applied. There is a close contact between urbanization and urban resilience. In general, enhancing the resilience level of the city is an effective method to solve or prevent some problems of the city. The interaction between urban resilience and urbanization is mainly reflected in population growth, economic development, and spatial expansion of cities. First, urbanization brings a large number of people into cities. Excessive population density and high consumption levels lead to increased demand for various resources in cities, which directly or indirectly damages or reduces the resilience of cities. Second, a higher level of urban resilience can promote a higher quality of urban urbanization. The main purpose of urban resilience is to provide material and immaterial conditions for the normal operation of the huge complex system of cities and to ensure that the exchange of matter, energy, and information of cities will not be greatly disturbed, which ensures the steady progress of the urbanization process. Third, a low level of urban resilience will restrict the urbanization process. If the level of urban resilience is too low, there will be more safety risks in the development process of a city, and the accident rate will be higher than that of ordinary areas. The high-quality development of a city will be difficult to sustain, and the level and quality of urbanization will inevitably be damaged. By studying the coupling relationship between them, we can acknowledge the status of urban resilience and know whether they can coordinate with each other, which is a reference for urban development.

3. Data Source, Research Method, and Index System

3.1. Data Source. The data in this paper are from the website of Anhui Provincial Bureau of Statistics, the Statistical Yearbook of Anhui Province (2012–2020), and the Statistical Yearbook of Hefei City (2012–2020) published on the website of the Hefei Municipal Bureau of Statistics from 2012 to 2020, and some data are from the statistical announcement on the website of Hefei Municipal Government.

3.2. Research Methods

3.2.1. Standardization of Data. Due to the dimensionless differences of various indicators, their effects on the research object can be divided into two kinds. Some indicators play a promoting role, while others play a weakening role. In this paper, the original statistical data are processed by extremum standardization, and the data are preliminarily processed by the dimensionless processing method. The following equations [21] are used for data preprocessing:

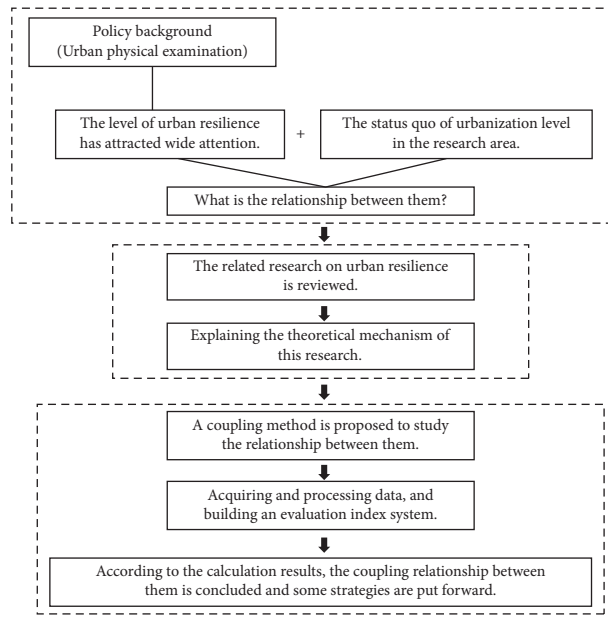

Figure 3: Flowchart for conducting this research.

$$Z_{ij} = \frac{\left(X_{ij} - X\min\right)}{\left(X\max - X\min\right)}, \tag{1}$$

$$Z_{ij} = \frac{\left(X\max - X_{ij}\right)}{\left(X\max - X\min\right)}. \tag{2}$$

Equation (1) is applicable to the positive indicator that the bigger the better for the system [22], and equation (2) is applicable to those negative indicators that the smaller the better. And i means the year, j means the index, and $X_{\max}$ and $X_{\min}$, respectively, mean the extreme value of the jth index in all years, namely, the maximum and minimum value. The standardized value is represented by Z_{ij}, and the original value is represented by X_{ij}.

3.2.2. Entropy Method. The entropy method to determine the weight is objective which can weaken the interference of subjective factors that was used in many research [23, 24] to determine the weight of various indexes. If a system has more entropy information, its structure will be more stable [25], and the lower the entropy of the index, the greater its weight [26]. For the sake of weakening the effects of subjective factors, the entropy method was chosen to confirm the weight of each index and to construct the evaluation systems in this paper.

3.2.3. Comprehensive Score Measurement. According to the standardized values of each index obtained after data preprocessing, then multiply them with their respective weights,

Table 1: Indicator system of urbanization level.

	First-level indicators	Weight	Second-level indicators	Weight	Type
Indicator system of urbanization level U_1	Urbanization of population	0.2354	The urbanization rate	0.1246	+
			Proportion of working population in secondary and tertiary industries	0.1108	+
	Urbanization of economy	0.3136	Ratio of the output value of secondary and tertiary industries in total output value	0.1621	+
			The average salary of employee	0.1515	+
	Urbanization of society	0.3193	Total retail sales of consumer goods per capita	0.1708	+
			Science and education expenditures	0.1485	+
	Urbanization of space	0.1317	Proportion of built-up area to urban area	0.1317	+

and then sum them, and the comprehensive index of the evaluation system of the urbanization level can be calculated. The equation is as follows:

$$U_{i=1,2} = \sum_{i=1}^{n} \omega_{ij}\mu_{ij}, \sum_{i=1}^{n} \omega_{ij} = 1. \quad (3)$$

In the above equation, ω_{ij} means the weight of second-level indicators; μ_{ij} means the standardized value of second-level indicators; i means the ith year; and j means the jth indicator.

3.2.4. Coupling Harmonious Degree Model. The concept of coupling in the field of physics was often used to explore the interaction or interaction between two or more systems under their own and external effects [27]. Therefore, the coupling degree model is chosen in this research to explore the coupling relationship. The equation is as follows:

$$C = 2 \times \left[\frac{(U_1 \times U_2)}{(U_1 + U_2)^2} \right]^{1/2}. \quad (4)$$

In the above equation, C means the coupling degree. U_1 means the comprehensive evaluation index of the urban resilience level; U_2 means the comprehensive evaluation index of the urbanization level. C can describe the degree of interaction and influence between systems, but it is hard to reflect the overall development level of the two systems [2]. Therefore, this paper further introduces the coordination degree model with the equation as follows:

$$D = \sqrt{CT}, \; T = \alpha U_1 + \beta U_2. \quad (5)$$

In the above equation, D means the coupling coordination degree and T means the comprehensive coordination index. D can more comprehensively evaluate the development status of the two systems. A high value of D indicates a high level of mutual promotion between systems. A low value of D indicates a low level of mutual restriction relation between systems [27]. α and β can be interpreted as the relative importance of two subsystems, and its relative size does not affect the basic model of coupling coordination degree of the overall situation. The sum of α and β is always equal to 1. Therefore, in this paper, the values of α and β are 0.5 according to relevant studies [28].

3.3. Index System

3.3.1. Indicator System of Urbanization Level. With reference to the research of Tong and Cao [29] and the actual needs of this paper, four first-level indicators of urbanization including population, social, spatial, and economy were selected, and one or two second-level indicators were selected from each first-level indicator according to the research needs. The index system of the urbanization level is shown in Table 1.

Determination of weights of various indicators: through dimensionless processing standardization values of the original data for correction (if the entropy method is chosen to confirm the weight, then all the data cannot be 0. So, all the data as a whole are increased by 0.01), a standardized table of values for the level of urbanization can be obtained. The weight of each index was obtained by entropy analysis, as shown in Table 2.

3.3.2. Index System of Urban Resilience Level. As referred to the relevant research [18], four first-level indicators of urban resilience including economy, ecology, society, and infrastructure construction were selected, and each first-level indicator was also subdivided into multiple second-level indicator systems, as shown in Table 3.

The weights of indicators of urban resilience can be determined in the same way as the weights of indicators of the urbanization level. The standardized values of urban resilience level indicators are shown in Table 4.

4. Research Results

The comprehensive score of U_1 and U_2 in each year and the coupling coordination degree are shown in Table 5, and we can acquaint the changes of numerical values in Figures 4 and 5.

In Table 5, after 2012, the change degree of C value is not obvious, but the change of D value is very clear, which confirms that D value can better reflect the relationship between the two systems. Based on the studies on similar problems [30, 31], the coupling coordination degree was divided into several levels. In this paper, the research methods and conclusions of previous scholars were adopted to divide the value of D into six levels, as shown in Table 6.

The comparison between Tables 5 and 6 shows that the coupling coordination level of urbanization and urban resilience was moderately unbalanced in 2011, mild

Table 2: Standardized values of various indicators of urbanization level.

	2011	2012	2013	2014	2015	2016	2017	2018	2019
The urbanization rate	0.01	0.16	0.28	0.39	0.50	0.65	0.79	0.89	1.01
Proportion of working population in secondary and tertiary industries	0.01	0.18	0.31	0.48	0.61	0.68	0.75	0.86	1.01
Ratio of the output value of secondary and tertiary industries in total output	0.01	0.09	0.16	0.32	0.39	0.55	0.70	0.86	1.01
The average salary of employee	0.01	0.12	0.19	0.30	0.42	0.53	0.65	0.89	1.01
Total retail sales of consumer goods per capita	0.01	0.07	0.13	0.28	0.35	0.43	0.51	0.58	1.01
Science and education expenditures	0.01	0.16	0.20	0.23	0.31	0.58	0.54	0.72	1.01
Proportion of built-up area to urban area	0.01	0.15	0.29	0.36	0.48	0.84	0.85	0.90	1.01

Table 3: Urban resilience index system.

	First-level indicators	Weight	Second-level indicators	Weight	Type
Index system of urban resilience level U_2	Resilience of economy	0.3250	Gross regional product per capita	0.0519	+
			Actual use of foreign capital	0.1730	+
			GDP growth rate	0.0558	+
			Household savings	0.0443	+
	Resilience of ecology	0.1896	Green space coverage in built-up areas	0.0674	+
			Park green area per capita	0.0356	+
			Capacity garbage disposal	0.0486	+
			Percentage of days with air quality reaching or better than grade II	0.0380	+
	Resilience of society	0.3167	Volume of post and telecommunication services per capita	0.1163	+
			The number of regular colleges and universities per 10,000 people	0.0384	+
			The number of health technicians per 10,000 people	0.0522	+
			Urban registered unemployment rate	0.0463	−
			The public security organ investigating and handling public order cases	0.0653	−
	Resilience of infrastructure	0.1687	Urban sewage treatment rate	0.0253	+
			The number of buses per 10,000 people	0.0651	+
			Urban road area per capita	0.0515	+
			Length of urban drainage pipes	0.0288	+

Table 4: Standardized values of various indicators of the urban resilience level.

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gross regional product per capita	0.01	0.11	0.20	0.30	0.38	0.48	0.61	0.74	1.01
Actual use of foreign capital	0.01	0.02	0.04	0.06	0.07	0.09	0.10	0.12	1.01
GDP growth rate	1.01	0.78	0.51	0.45	0.38	0.29	0.13	0.13	0.01
Household savings	0.01	0.15	0.27	0.34	0.45	0.55	0.61	0.79	1.01
Green space coverage in built-up areas	0.68	0.04	0.40	1.01	0.59	0.38	0.62	0.05	0.01
Park green area per capita	0.97	0.01	0.12	0.75	0.78	0.82	1.01	0.75	0.74
Capacity garbage disposal	0.01	0.16	0.23	0.33	0.45	0.65	0.91	0.86	1.01
Percentage of days with air quality reaching or better than grade II	0.77	1.01	0.68	0.63	0.26	0.31	0.01	0.41	0.36
Volume of post and telecommunication services per capita	0.01	0.03	0.06	0.08	0.12	0.24	0.16	0.61	1.01
The number of regular colleges and universities per 10,000 people	0.01	0.16	0.35	0.52	0.77	0.83	0.80	0.65	1.01
The number of health technicians per 10,000 people	0.01	0.12	0.21	0.27	0.33	0.45	0.57	0.69	1.01
Urban registered unemployment rate	0.01	0.07	0.36	0.57	0.65	0.58	0.92	0.98	1.01
Public order cases handled by the public security organ	0.06	0.42	0.01	0.08	0.46	0.90	0.89	1.01	0.78
Urban sewage treatment rate	1.01	0.55	0.59	0.63	0.94	0.96	0.97	0.73	0.01
The number of buses per 10,000 people	0.01	0.06	0.14	0.27	0.39	0.52	0.81	0.80	1.01
Urban road area per capita	0.83	0.01	0.21	0.17	0.27	0.35	0.60	0.82	1.01
Length of urban drainage pipes	0.01	0.44	0.62	0.85	0.44	0.55	0.81	0.95	1.01

disorder in 2012, and primary coordination in 2013. However, in 2014 and 2015, the situation improved a lot, and the coordination degree between the two was intermediate coordination. From 2016 to 2019, the coupling coordination level was in advanced coordination. Overall, the coupling coordination degree of them is improving year by year, and the coupling coordination level is getting better and better, as shown in Figure 5.

Table 5: Coupling coordination degree from 2011 to 2019.

	The comprehensive score of urbanization level U_1	The comprehensive score of urban resilience level U_2	Coupling C	The degree of coupling coordination D
2011	0.010	0.245	0.388	0.222
2012	0.128	0.185	0.983	0.393
2013	0.214	0.227	1.000	0.470
2014	0.328	0.342	1.000	0.579
2015	0.426	0.367	0.997	0.629
2016	0.596	0.437	0.988	0.715
2017	0.673	0.514	0.991	0.767
2018	0.805	0.569	0.985	0.823
2019	1.010	0.813	0.994	0.952

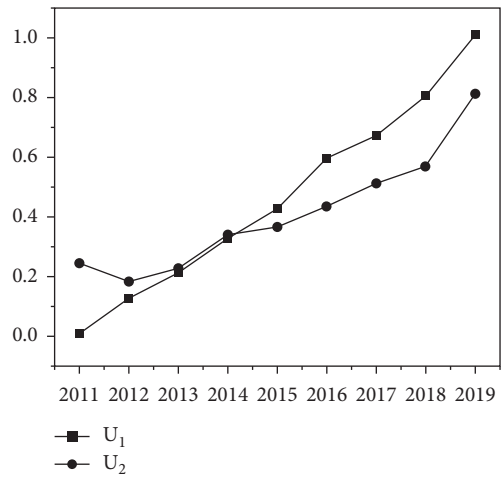

Figure 4: The changes of comprehensive score of U_1 and U_2.

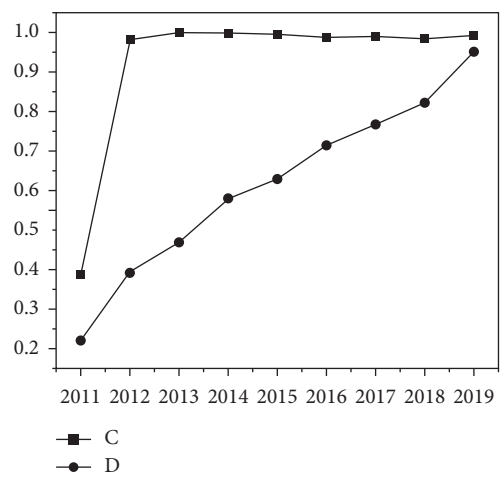

Figure 5: The changes of C and D.

Table 6: Classification of coupling coordination degree.

Coupling coordination degree interval	Coupling coordination level
0.000–0.199	Serious disorder
0.200–0.299	Moderate disorder
0.300–0.399	Mild disorder
0.400–0.499	Primary coordination
0.500–0.699	Intermediate coordination
0.700–1.000	Advanced coordination

5. Conclusions

Before 2013, the coupling relationship between the level of urban resilience and urbanization in Hefei was in the phase of imbalance. After 2014, it gradually coupled and changed to the direction of high coordination. What is remarkable is that the coupling coordination level is at a high-level coordination level from 2016 to 2019. Under the background that the urbanization of the city will be in the third stage of Northam Curve for a long time. In the future, the urbanization level of Hefei will be in a state of slow growth for a long time. However, in order to achieve a higher coupling coordination level, it is necessary to consider improving the city's resilience. That is to say, the future development of Hefei should pay more attention to the concept of resilient development and do enough work of a resilient city.

According to the above conclusions and statements, the author proposes the following two suggestions: one is that in the context of slower urbanization in the future, a higher degree of coupling and coordination depends on increasing the level of resilience of cities. What should be paid more attention to is infrastructure and ecology and to enhance their resilience. The other one is that to build up the thinking of resilience in the development of the city and to seek methods to enhance its resilience level which can improve the ability of cities to resist all kinds of disaster risks. In this regard, we can learn from Rotterdam's ideas and practices in building resilient cities, such as the "resilient scan" tool they used in urban planning and the participation of residents in building resilient cities. The city of Hefei has a great spillover effect and polarization effect [32], which has greatly affected the urbanization process of surrounding counties and even cities. Hefei, as nuclear city of Anhui province, the importance of enhancing its urban resilience level should be attached because there will be a great significance of other cities that be radiated and affected by Hefei.

Data Availability

The data used to support the results of this study are included within the article, and the original statistical data in this paper are from the website of the Anhui Provincial Bureau of Statistics (http://tjj.ah.gov.cn/).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This study was supported by the Scientific Research Program of Anhui Jianzhu University, No. JY2021-C-026.

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