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Analysis of Settlement Space Environment along China's Grand Canal Tianjin Section Based on Structural Equation Model—Case Study of 44 Typical Settlements

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Abstract: The settlement space along China's Grand Canal is an important part of cultural heritage, boasting high value of conservation and inheritance as a museum of local culture in an active state. The paper is aimed at revealing the current situation and satisfaction with the settlement space environment along China's Grand Canal Tianjin Section from the perspective of resident perception. We set up a structural equation model to perform an empirical analysis of the inherent relation of the components of the settlement space environment along China's Grand Canal Tianjin Section and the inherent law influencing its current state. The research results show that the ecological factor of life along China's Grand Canal exerted a positive influence on the ecological factor of production and the path coefficient was 0.344. The ecological factor of life and the factor of accessibility were in a relation of positive influence and the former had the most prominent influence on the latter, with a path coefficient of 0.534, while the path coefficient of the influence of the latter on the former was 0.131. The factor of social culture exerted a positive influence on the ecological factor of life, with the path coefficient being 0.765. The research conclusion analyzed the realistic difficulties of the settlement space environment along China's Grand Canal, revealed the inherent law between different surveyed factors and provided basic reference for feature extraction, evaluation and optimized development of the settlement space along China's Grand Canal.

Keywords: China's Grand Canal; settlement space environment along the Canal; status quo; survey evaluation and analysis; structural equation model

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1. Introduction

China's Grand Canal, stretching 3200 km and boasting a long history of more than 2500 years, is a great project created in ancient China and the world's longest and largest canal of outstanding cultural value. The settlement space environment along China's Grand Canal, as the center of the heritage, has close ties with the production, life, ecology, culture and wisdom of generations of ancestors and has a high value of conservation and inheritance [1]. In 2019, the General Office of the CPC Central Committee and the General Office of the State Council issued the Guideline for the Conservation, Inheritance and Utilization of the Culture of China's Grand Canal, along with the Construction Plan for the Great Wall, the Grand Canal and the Long March National Cultural Park to comprehensively promote their conservation and inheritance. From June to August 2020, the National Development and Reform Commission (NDRC), together with the National Cultural Heritage Administration, the Ministry of Water Resources, the Ministry of Ecological

Environment and the Ministry of Culture and Tourism, prepared four special programs for cultural heritage conservation and inheritance—namely, canal river system treatment, management and conservation, ecological environment conservation and restoration and integrative development of culture and tourism—and guided the provincial (municipal) governments along the Canal and established the "multiple pillars" planning system for the conservation and inheritance of China's Grand Canal culture. Although the construction of China's Grand Canal cultural belt and cultural heritage conservation are in full swing nationwide, with urbanization and development, the settlement space environment along China's Grand Canal still suffers prominent problems such as unclear heritage resources, low inheritance and utilization quality, contractions between Canal conservation and rural construction, a severe environmental situation, serious occupation of the ecological space and cooperative mechanisms urgently needing strengthening [2]. The settlements along China's Grand Canal have a history of 100 years since the 1920s when scholars began to research the influence of the urban settlements and ancient sites along the canal system. Price, A.G. proposed that the success of the Panama Canal also revealed the contents of the settlements of the White people in tropical areas [3]. In the period of research development from the 1950s to the turn of the century, the research on the settlements along the Canal focused on the irrigation system and the settlements, the settlements along the Canal, the environmental management of the cities along the Canal and public participation and the changes in land use. Now, the research on the settlements along the Canal has stepped into the fast lane of development and involves aspects such as landscape evolution, regional conception, spatial pattern, cultural landscape and ecological cities. Garcia, M. C. researched the evolution of traditional landscapes around the Segura River in Alicante [4]. Lavoie, C. established the theoretical frameworks of the "environment of memory" and the "helper of memory" of the settlements along the Logan Canal to explain the significance of people's discovery of the landscape, transcending time and culture [5]. Biscaya, S. et al. investigated the possibility of developing an intelligent ecological urban corridor along the Manchester Canal [6].

The conservation and utilization of the settlement along China's Grand Canal has been a key issue of the research and practice of academic circles. Scholars have prioritized their research on the key cities and towns along China's Grand Canal in terms of field investigation, evolution law and overall conservation. (1) In the 1990s, Mr. Fu Chonglan published his work "Development History of the Cities along China's Grand Canal" (1985), which remarkably promoted the systematic perception of the academic circles for the cities along the Canal. Some scholars researched the characteristics and vicissitudes of the settlements in the cities and towns along the Canal. (2) Research on the settlement along China's Grand Canal entered a stage of rapid growth and a multitude of literati emerged from the late 1990s to the period before the application of China's Grand Canal for the list of World Heritage Sites in 2014. From 2003, the City Planning Review planned special investigations based on "Historical Blocks in the Project of the Famous National historic and Cultural Center" and made fundamental investigations of the status quo of more than 10 ancient towns along the Beijing-Hangzhou Grand Canal, the Shandong Canal, the Northern Suzhou Canal and the canal in the region south of the Yangtze River [7]. An enormous amount of scholars performed in-depth analyses of the valued characteristics of the settlements along the Canal from the perspectives of the relationship between the city and the canal and the patterns, distribution laws, cultural characteristics, evolution law and occurrence mechanism of the settlements and proposed planning, methods and suggestions for conservation [8–10]. (3) In the post-application era, the research on the settlement along China's Grand Canal put more emphasis on the innovation of the methods, perspectives and technical measures of research. For instance, research was made to analyze the characteristics of the space pattern of the water adaptability to the settlement from the perspective of hydrology [11]. Starting from the famous historic and cultural towns along China's Grand Canal, researchers studied the characteristics and laws of historical evolution by means of field investigation, literature review and spatial analysis [12]. Some scholars

advanced a new classification method to help determine the heritage value of the canal cities from the perspective of historical events [13]. Through analyzing the spatiotemporal variations of land urbanization and socioeconomic benefits of the cities along China's Grand Canal, some scholars put forward new thinking for action mechanisms of city development imbalance on the macro scale [14]. (4) As to the research on the rural settlements along the Canal, achievements were also made from the microscopic angle to analyze the spatial form, evolution law and resident perception in recent years. Some scholars analyzed tourists' spatial cognition of historical and cultural blocks of the towns along China's Grand Canal to help promote sustainable heritage tourism [15]. Furthermore, some scholars also have made some progress on the evaluation of environmental characteristics of the canal cities by using the quantitative method of urban morphology from dynamic visual perception [16,17].

Above all, a large quantity of local cultural heritage is still awaiting excavation and classification, and the relations between canal heritage and rural settlement conservation and urbanization still need further discussion. The past research rarely investigated in the status quo of the settlement space environment along China's Grand Canal. In the present study, with China's Grand Canal Tianjin Section as an example, we performed a field investigation of the rural settlement space environment along China's Canal with the aim of revealing the existing status quo and satisfaction with the settlement space environment along China's Grand Canal Tianjin Section from the perspective of resident perception. We conducted an empirical analysis of the relations between the factors of investigation of the settlement space environment along China's Grand Canal Tianjin Section through the structural equation model. We proposed the framework of the factor of investigation into the settlement space environment along the Canal, applied the structural equation model to make quantitative analysis of the 44 typical settlements along Tianjin Section and analyzed the realistic plights of the settlement space along the Canal. This research provides techniques and references to probe the settlement space environment of other areas. The conclusion of the paper is valuable for clarifying the realistic plights and principal contradictions of the settlement space along the Canal in order to provide references for the protection, development and spatial optimization of the settlement space along the Canal.

2. Research Methods

2.1. Study Area

China's Grand Canal Tianjin Section spans an area of up to 182.6 km, and the core surveillance area grosses 670 km^2 (hereinafter referred to as "Tianjin Section"). The fork estuary of the northern and southern parts of the Canal covering 71 km is the section of world cultural heritage, comprising 16 township settlements and up to 380 village settlements. However, the cultural heritage area consists of merely one famous state-level historical and cultural town, one city-level historical and cultural town, one city-level historical and cultural village and 28 canal heritage sites of various kinds, highlighting the severe situation of canal settlement conservation. The selection of the typical rural settlement space of China's Grand Canal Tianjin Section was based on diversity and balance to ensure the typicality and representativeness of the research cases. By referring to the history of the Canal and a variety of county annals, we performed a field investigation of 44 typical canal settlements (Figure 1).

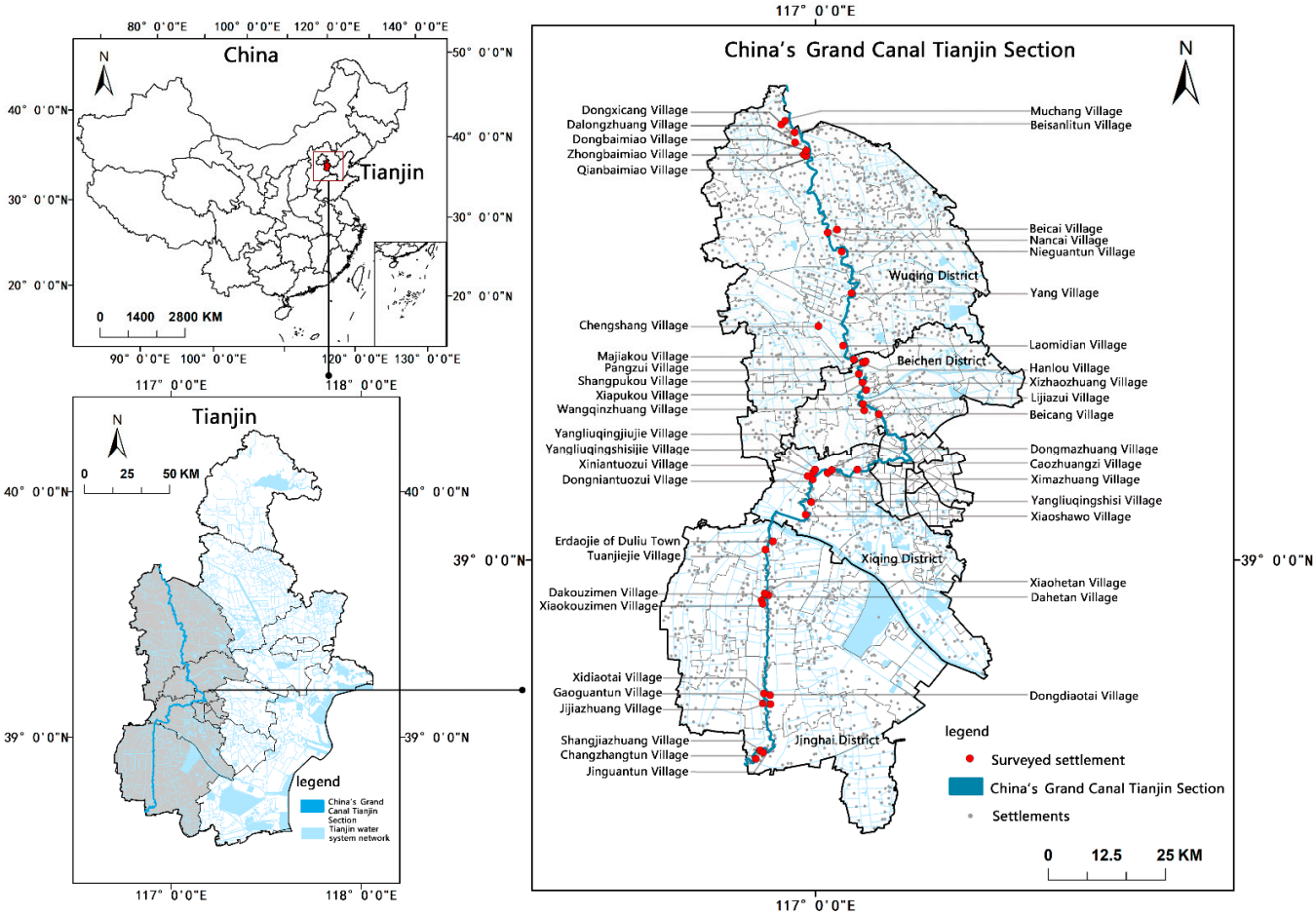

Figure 1. Spatial distribution maps of 44 typical settlements along the Tianjin Section.

2.2. The Structural Equation Model

2.2.1. Connotation of the Structural Equation Model

The approach of the structural equation model originated from Swell Wright's path analysis theory in the 1920s. In the 1970s, Swedish statistician and psychometrician Karlg Joreskog put forward the concept of the structural equation model (1973). The structural equation model integrates the interdisciplinary achievements of psychology, sociology and economics and enjoys conspicuous advantages over traditional multivariate analysis. On the one hand, the structural equation model integrates and optimizes traditional multivariate analysis, has the advantages of factor analysis and path analysis, considers error factors and improves assumed conditions. On the other hand, the structural equation model is suitable for analyzing the linear equation system in interrelation. It can analyze the inherent law and connection of different variables, improve variant structures and perform exploratory and confirmatory analyses [18]. For this reason, it can be widely applied in diverse fields such as marketing management, behavioral analysis, psychological measurement and social research.

2.2.2. Practical Application of the Structural Equation Model

Scholars have carried out substantial detailed research on the methods of applying the structural equation model. Overseas scholars have performed considerable research on the practical methods of the structural equation model. The first was the detailed description of the correct operation and utilization of the structural equation model, elaborating on the model specification, identifiability, data and estimation, goodness of fit, parameter and standard error and substitution model so that readers could fully and correctly use the structural equation model [19–21]. Then, a bounty of research was conducted on the

modeling approach, checking and analysis and model evaluation [22–24]. The domestic research on the structural equation model started late. Hou Jietai was the first to publish works to systematically introduce the structural equation model and its application [25]. A number of scholars have presented discussions on the theories, characteristics, practice, modification techniques and applications of the structural equation model [26–28]. The research findings on the applications of the structural equation model in settlement space and geography chiefly center on rural tourism, tourists' loyalty, satisfaction, service quality, resident psychological perception, evaluation criteria and community participation.

Albacete-Sáez, C.A. proposed a scale to assess the lodging and service quality of rural tourism to provide a useful tool for the managers in charge of lodging services for rural tourism [29]. Auh, S. performed a modeling analysis of the satisfaction with the rural communities [30]. Rashidpour, L. adopted a questionnaire and descriptive research to design a community-based management model and its application in the sustainable development of the rural area in Iran [31]. Martinovska, S.A. demonstrated whether the psychological structure of farmers decides the success of agricultural development [32]. Bunkus, R. put forth a model that can capture the interactions between precise agricultural relations and rural attachment and investigated the direct and indirect influence of the density of the farmers on these interactions [33]. Leković, K. discussed the issues relating to the images of the rural tourist destinations from functional, mixed and psychological dimensions and concluded that the psychological dimension exerted the largest influence on the images of the rural tourist destinations [34].

To sum up, the research on the theories and practical applications of the structural equation model has been in constant development. The research on the settlement space chiefly focuses on tourist loyalty, satisfaction, service quality, resident psychological perception, rural tourism, evaluation standards and community participation. Nevertheless, the inherent relations between the components of the settlement space environment still need further examination to explore the inherent law influencing the settlement space environment.

2.3. Building of the Structural Equation Model of the Settlement Space Environment along Tianjin Section

2.3.1. The Principle of Data Collection

The data of the paper were collected through a field investigation of the settlements along China's Grand Canal Tianjin Section, with questionnaires and semi-structured interviews from April 2020 to April 2021. We distributed 1050 questionnaires to the residents of 44 representative settlements along China's Grand Canal Tianjin Section and received 1033 copies. The questionnaire included quantitative and qualitative questions. Quantitative questions were expressed with a Likert scale and focused on the components of the rural settlement space environment along China's Grand Canal. Qualitative questions were lodged in the form of multiple choice, including basic information such as gender, age group, place of residence, attributes of residence, time of life, permanent residents and occupations as well as subjects on the characteristics and demands of the daily behaviors of the residents and the historical heritage in the settlements. Quantitative questions were devised on 18 observation indexes such as the ecological features of life and production, accessibility and social culture of the rural settlement space. Generally speaking, the questionnaires gave full consideration to the factors influencing the rural settlement space along China's Grand Canal. The data collection points adequately reflect the integrality and diversity of the rural settlement space along China's Grand Canal Tianjin Section, the status quo of the rural settlement space and the typicality and representativeness of the components.

2.3.2. Data Sample Testing

The SPSSAU software was applied to analyze the 1033 returned questionnaires, setting the sample as >70% invalid to guarantee the validity of sample analysis. In total, 196 invalid and 837 valid samples were tested, with a validity rate of 81.03%. The analysis of the structural equation model had some requirements for sample content N. Some scholars pointed out that "the sample content should be more than 10 times of the amount of the surveyed questions (indexes) or above 5 times of the liberal estimated parameter t" [35]. The sample indexes in the research comprised 35 qualitative and quantitative questions, and the valid samples collected met the requirements of statistical research (Table 1).

Table 1. Test results of samples.

Item	Frequency	Percentage	Cumulative Percentage
Null	196	18.97%	18.97%
Valid	837	81.03%	100.00%
Total	1033	100.0%	

2.3.3. Presupposition of the Factor of Investigation of the Settlement Space along the Canal

The investigated factors influencing the settlement space environment along the Grand Canal were mainly determined by the factors of life and ecology of production as well as exclusive factors. On the one hand, judged from the connotation and spatial scope of life and ecology of production, the spatial scope of the land for life and ecology of production was composite [36]. For instance, the space for ecological greening and the canal river system are important for daily life and entertainment as the carriers of the ecological space. Agricultural production space such as cultivated land, forest and garden plots had similarly important ecological functions; therefore, the settlement space environment along China's Grand Canal could be divided into ecological factors for life and ecological factors for production. On the other hand, the factor of social culture and that of accessibility could be taken as the exclusive factors of investigation into the rural settlements along the Canal. The exclusive characteristics of the settlement space environment along the Canal were flowing canal heritage. Hence, cognition investigation into the historical heritage and the history and culture of China's Grand Canal was prioritized, emphasized the significance of the investigation and was good for the understanding of the cultural connotation and social evaluation of the rural settlement space along the Canal. Some scholars held the view that the space for life and ecology of production could not cover all types of land use and proposed the division of "space for life, ecology of production + guarantee space" and "space for life, ecology of production + regional facility space" [37–39]. Therefore, we took the space for transportation service with protective functions as the factor of accessibility to supplement the investigation of exclusive factors.

Above all, the factors of investigation into the settlement space environment along China's Grand Canal consisted of the ecological factors of life and production, accessibility and social culture (Figure 2). (1) The ecological factor of life was composed of residential buildings and space for public activities, commercial activities, cultural services, educational service, medical services, canal river system and ecological greening, aimed at analyzing the perception and evaluation of the residents regarding the physical environment of their living space and the status quo of the natural environment. (2) The ecological factor of production consisted of the space for industrial production in the rural settlement, the space for agricultural production and the situation of migrant workers away from the village, so as to know the satisfaction of the residents with the status quo of the industries in the settlements and their participation. (3) The factor of accessibility comprised the convenience of the space for transportation service and traffic congestion in a bid to know the perception and experience of the residents regarding their daily life and production. (4) The factor of social culture was used to evaluate the utilization of the historical relics and

cultural space (guild halls, temples, academies of classical learning, memorial archways, tea houses, theatrical stages, wharves, etc.) and the perception of the historical, cultural or heritage value of China's Grand Canal.

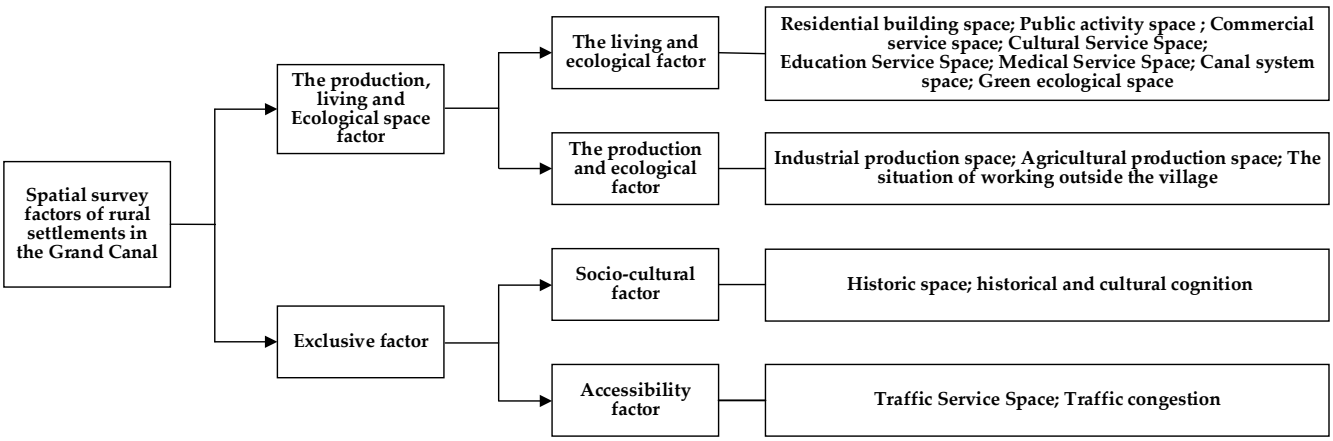

Figure 2. A framework of spatial survey factors of rural settlements along China's Grand Canal.

2.3.4. Relation Assumption of Investigation Factors of Settlement Space Environment along Tianjin Section

The relations between multidimensional variables were established according to the analytical method of the structural equation model, with latent variables expressed with ovals, observational variable with rectangles, and the influence relation between latent variables and observational variables and between latent variables with one-way arrows. First, as the core factor of the rural settlement space along China's Grand Canal, the ecological factor of life was an important carrier for the residents to perceive the quality of life and had the functions of residence, leisure, recreation and entertainment. Second, the ecological factor of production was a driving factor of the rural settlement space environment along China's Grand Canal and an important source of the stable life of the residents and had diverse service functions such as food production, commodity exchange and economic growth. Third, the factor of accessibility was a factor guaranteeing the livability and development of the rural settlement space environment along China's Grand Canal and the basic condition for daily travel of the residents and had the functions of connection, security and leisure. Finally, the factor of social culture was a supporting factor of the rural settlement space environment along China's Grand Canal and a central part of the residents' cultural confidence, and provided important supporting factors of the inheritance, protection and development of the settlement space. The structural equation model to investigate the settlement space along China's Grand Canal should be established according to the framework with four latent variables and 15 observational variables expressed in the path schema (Figure 3).

Hypothesis 1 (H1). *Ecological Factor 1 of life and ecological Factor 2 of production have a positive correlation.*

Hypothesis 2 (H2). *Ecological Factor 1 of life and Factor 3 of accessibility are in interplay.*

Hypothesis 3 (H3). *Factor 4 of social culture and ecological Factor 1 of life have a positive correlation.*

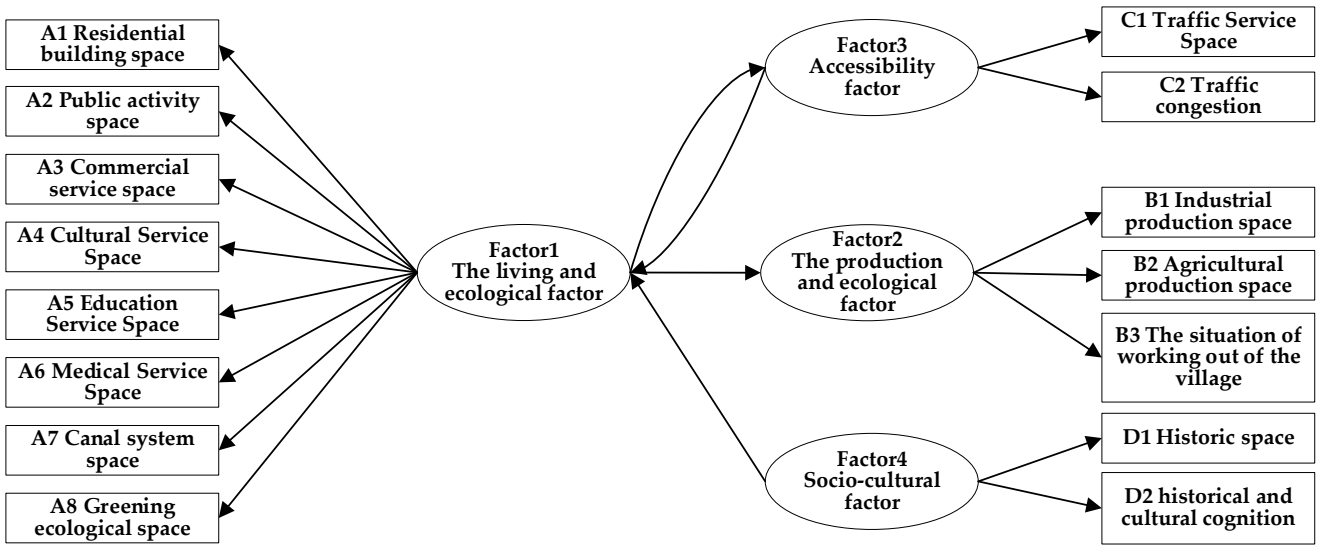

Figure 3. A structural equation model for spatial environment investigation of settlements in China's Grand Canal.

3. Results

3.1. Descriptive Analysis of the Basic Index of Settlement Space Environment Investigation along Tianjin Section

3.1.1. Basic Attributes of the Investigated Group

The field investigation was conducted in 44 settlements along China's Grand Canal Tianjin Section. At present, the residents in the rural settlements along China's Grand Canal are mostly middle-aged and elderly. To guarantee valid and rational distribution of survey data, gender and age structures of the interviewed should have a balanced distribution as much as possible.

According to statistical analysis of the background information of valid samples (Table 2), (1) from the perspective of gender, more than 50% of the respondents were men and 48.51% were women; (2) from the perspective of age group, most of the sample was aged 41–50, with a proportion of 23.30%; (3) more than 30% of the sample resided in the Jinghai District (a settlement along the southern Grand Canal) and more than 70% lived in the local area; (4) more than 60% of the sample have lived there for over ten years; (5) most of the respondents who were part of the permanent population were families of three, accounting for 27.84% of the total, and most respondents were farmers (27.72%); and (6) most respondents worked near the local area, with a proportion of 50.06%.

As for the feature information, the interviewees tilled land, took care of family affairs (children and the elderly), had part-time jobs and engaged in the animal husbandry industry (Table 3). According to the cross-over analysis of the different places of residence, six items in the questionnaire displayed the significance level of 0.01 (chi = 59.163, $p = 0.000 < 0.01$). Table 3 shows that about 41.67% of interviewees in the Jinghai District (a settlement along the southern Grand Canal) performed farm work, notably higher than the average rate of 29.15%. About 49.43% of interviewees in the Beichen District (a settlement along the northern Grand Canal) took care of family affairs (children and the elderly), much higher than the average level of 39.19%. About 18.26% of the interviewees in Wuqing District (a settlement along the northern Grand Canal) worked as migrant workers in other places, conspicuously higher than the average rate of 10.51%.

Table 2. Basic information of survey population in typical settlement space.

Item	Option	Frequency	Percentage (%)	Item	Option	Frequency	Percentage (%)
Gender	Man	431	51.49	Domicile place	Local	667	79.69
	Female	406	48.51		Not local	170	20.31
Age group	Under 18	49	5.85	Duration of residence	Within 1 year	51	6.09
	18–25	75	8.96		1–3 years	88	10.51
	26–30	79	9.44		3 to 10 years	154	18.40
	31–40	133	15.89		Over 10 years	544	64.99
	41–50	195	23.30	Resident household size	Singlehood	55	6.57
	51–60	163	19.47		2 people	106	12.66
	Over 60	143	17.08		3 people	233	27.84
Residence location	Wuqing District	241	28.79		4 people	232	27.72
	Beichen District	174	20.79		Over 5 people	211	25.21
	Xiqing District	158	18.88	Occupation	Government institution employee	54	6.45
	Jinghai district	264	31.54		Company employee	85	10.16
Workplace	Near the location	419	50.06		Worker	121	14.46
	Tianjin downtown	107	12.78		Individual private	119	14.22
	Non-local town	65	7.77		Farmer	232	27.72
	No work	246	29.39		Student	75	8.96
					Unemployed	151	18.04

Table 3. Daily occupation of interviewees in typical settlement space.

Cross Summary Table					
	Residence Location (%)				
Item	**Wuqing District (*n* = 241)**	**Beichen District (*n* = 174)**	**Xiqing District (*n* = 158)**	**Jinghai District (*n* = 264)**	**Summary (*n* = 837)**
Tilling land	73 (30.29)	30 (17.24)	31 (19.62)	110 (41.67)	244 (29.15)
Animal husbandry	36 (14.94)	23 (13.22)	11 (6.96)	46 (17.42)	116 (13.86)
Part-time job	74 (30.71)	57 (32.76)	47 (29.75)	83 (31.44)	261 (31.18)
Staying at home (taking care of children and the elderly)	83 (34.44)	86 (49.43)	61 (38.61)	98 (37.12)	328 (39.19)
School	23 (9.54)	15 (8.62)	11 (6.96)	34 (12.88)	83 (9.92)
Migrant work	44 (18.26)	13 (7.47)	17 (10.76)	14 (5.30)	88 (10.51)

Chi-square test: $\chi^2 = 59.163$ $p = 0.000$.

Table 4 shows that the interviewees primarily surfed online, watched TV, took exercise, chatted or had parties in their spare time. According to the cross-over analysis of different places of residence, seven multiple choice questions displayed the significance level of 0.01 (chi = 59.353, $p = 0.000 < 0.01$). Table 4 indicates that 45.98% of interviewees in the Beichen District (a settlement along the northern Grand Canal) surfed online or watched TV, much higher than the average of 39.43%. About 34.48% of the interviewees in the Beichen District (a settlement along the northern Grand Canal) read books or newspapers, remarkably higher than the average rate of 27.84%. About 45.23% of the interviewees in Wuqing District (a settlement along the northern Grand Canal) exercised, much better than the average level of 36.8%. About 50.00% of interviewees in the Beichen District (a settlement along the northern Grand Canal) chatted or had parties, largely higher than the average rate of 39.43%. About 27.59% of the interviewees in the Beichen District (a settlement along the northern Grand Canal) played cards, strikingly higher than the average proportion

of 21.74%. About 26.89% of the interviewees in the Jinghai District (a settlement along the southern Grand Canal) seldom went out, apparently higher than the average rate of 18.88%.

Table 4. Leisure behaviors of interviewees in typical settlement space.

Cross Summary Table					
	Residence Location (%)				
Item	**Wuqing District (*n* = 241)**	**Beichen District (*n* = 174)**	**Xiqing District (*n* = 158)**	**Jinghai District (*n* = 264)**	**Summary (*n* = 837)**
Surfing online or watching TV	97 (40.25)	80 (45.98)	43 (27.22)	110 (41.67)	33 (39.43)
Reading books, newspapers, etc.	76 (31.54)	60 (34.48)	38 (24.05)	59 (22.35)	23 (27.84)
Exercising outside	109 (45.23)	67 (38.51)	43 (27.22)	89 (33.71)	30 (36.80)
Chatting outside	104 (43.15)	87 (50.00)	57 (36.08)	82 (31.06)	33 (39.43)
Playing cards	43 (17.84)	48 (27.59)	28 (17.72)	63 (23.86)	18 (21.74)
Go out rarely	45 (18.67)	21 (12.07)	21 (13.29)	71 (26.89)	15 (18.88)
Other	17 (7.05)	5 (2.87)	20 (12.66)	36 (13.64)	78 (9.32)

Chi-square test: $\chi^2 = 59.353$ $p = 0.000$.

3.1.2. Characteristics Analysis of Investigation Factors of Settlement Space Environment along Tianjin Section

We carried out descriptive analysis of the observational variables to judge the overall information of the data. Table 5 shows that the present data have no abnormal value and a descriptive analysis of the average value of the observational variables can be directly made. On the whole, the observational variables can basically accept such normal characteristics.

Table 5. Basic indexes of observed variables in typical settlement space.

Basic Indicators						
Name	**Sample Size**	**Minimum**	**Maximum**	**Average**	**Standard Deviation**	**Median**
A1 Residential building space	837	1.000	5.000	3.026	1.163	3.000
A2 Public activity space	837	1.000	5.000	3.404	1.096	4.000
A3 Commercial service space	837	1.000	5.000	3.276	1.062	3.000
A4 Cultural service space	837	1.000	5.000	3.167	1.103	3.000
A5 Education service space	837	1.000	5.000	3.223	1.087	3.000
A6 Medical service space	837	1.000	5.000	3.188	0.994	3.000
A7 Canal system space	837	1.000	5.000	3.165	1.134	3.000
A8 Green ecological space	837	1.000	5.000	3.363	1.088	3.000
B1 Industrial production space	837	1.000	5.000	2.708	1.119	3.000
B2 Agricultural production space	837	1.000	5.000	2.903	1.211	3.000
B3 The situation of working out of the village	837	1.000	5.000	2.274	1.095	2.000
C1 Traffic service space	837	1.000	5.000	3.452	1.066	4.000
C2 Traffic congestion	837	1.000	5.000	3.860	1.011	4.000
D1 Historic space	837	1.000	5.000	2.973	1.064	3.000
D2 Historical and cultural cognition	837	1.000	5.000	2.912	1.130	3.000

The average value of the observational variables shows that the residents were generally satisfied with the overall settlement space environment along China's Grand Canal, with the evaluation results being the factors of accessibility, ecology of life, social culture and ecology of production in the top–bottom sequence. The analysis is given below.

In terms of the ecological factor of life, the description shows that the residents were generally satisfied with the ecological factor of life, at an average value of 3.23. According to the specific observational variables, the satisfaction with the A2 public activity space was the highest, at 3.40, followed by 3.36 for the A8 greening space and 3.03 for the A1 residential building space. According to the field investigation, most residential buildings had the typical characteristics of the rural areas in the North China Plain. The yard layout

was chiefly of the type of "one house + two compartments", and seldom the types of "one house + one compartment", "square + reversely-set house" and "one house + one yard". Residential buildings principally featured red clay bricks, red purple clay tile roofs and wooden doors and windows. The rural settlements severely influenced by urbanization have been rebuilt from bungalows to buildings to the satisfaction of the residents. However, some residential buildings have been in disrepair, of poor quality and to the poor satisfaction of the residents.

In terms of the ecological factor of production, the description shows the overall satisfaction with the ecological factor of production was rather low, merely at 2.63. According to the specific observational variables, many interviewees in B3 left their villages to work for others, too much in the view of 25.36% of the interviewees and comparatively much to 31.75% of the interviewees. The satisfaction degree with the space for industrial production in B1 and agricultural production in B2 was extremely low. According to the field investigation, only a few young people were engaged in agricultural production in the settlement space along China's Grand Canal, nearly one fourth of the interviewees did not work in agricultural production and most agricultural labor forces were the left-behind elderly and women. Most young people carried out migrant work in other places. Nearly 50% of the interviewees said that the gains of agricultural production of each local household could merely meet their demand for daily life and they had to work for others to subsidize their long-terms goals such as education for their children and marriage. Generally speaking, some rural settlement space suffered problems such as low productivity, backward modes of operation, low income of the farmers and slow development of rural industries. Rapid urbanization led quantities of middle-aged and young people to work in cities and few are engaged in traditional agriculture.

In terms of the factor of accessibility, the description shows that the overall evaluation of the factor of accessibility was better than other factors, and the average value was 3.66. The specific observational variables show that the satisfaction degree with the transportation service space was 3.45 in C1 and the figure for traffic congestion was 3.86 in C2, indicating that the transportation service function of the settlement space along China's Grand Canal was comparatively satisfactory and the recognition degree of the residents was relatively high. The field investigation shows that although the basic transportation function could be met, some settlement space still faced problems such as incomplete road facilities, simple underlying surface structure and narrow, uneven roads.

In terms of the factor of social culture, the description shows that the overall evaluation of the factor of social culture was generally satisfactory, with the average value being 2.94. The specific observational variables show that the historical and cultural space were not ideally utilized, with the degree of satisfaction with the space in historical heritage in D1 being 2.97 and the perception of the historical, cultural or heritage value in D2 being 2.91. According to the field investigation, the historical heritage sites in the settlement space dotted both sides of the Canal, including temples, memorial archways, guild halls, tea houses, theatrical stages, academies of classical learning, wharves, ruins of ancient city, old trees, ancient stelae and heritage of irrigation works. Nonetheless, the investigation shows that the people knew little about the history and culture of China's Grand Canal and the settlements along it, and only a small number of the elderly or the inheritors of intangible heritage knew a little.

3.2. The Structural Equation Model Testing

3.2.1. Validity and Reliability Testing

Validity and reliability testing of the observational variables should be made in the structural model of the factors investigating the settlement space along China's Grand Canal to determine the suitability of the prediction model (Table 6). Validity analysis could test the reliability of the observational data. The validity testing result in Table 5 shows that the Cronbach α coefficient value of 15 observational variables was 0.842, indicating higher data validity. Regarding whether the validity research is suitable and significant

for analytical investigation, Table 6 shows that the KMO value is 0.885, higher than 0.8, indicating that the research data is fairly suitable for extracting information and has validity.

Table 6. Reliability and validity test.

Number of Terms	15
Cronbach α coefficient	0.842
KMO value	0.885
Bartlett spherical value	4138.326
df	105
p-value	0.000

3.2.2. Factor Test Analysis of the Structural Equation Model

To research the compressed information by means of factor analysis, it is required to primarily analyze whether the research data are suitable for factor analysis. The above table shows that the KMO value is 0.885, which meets the premise of factor analysis, indicating that the data can be used for research on factor analysis. The data pass the Bartlett spherical degree test ($p < 0.05$), indicating that the research data are suitable for factor analysis.

According to factor extraction, Table 7 analyzes the amount of information of factor extraction. It shows that factor analysis totally extracts four factors and the characteristic root values are greater than 1. The variance interpretation frequencies of the first four factors after rotation in the cross-section data are 34.870%, 10.582%, 8.175% and 6.861%, respectively, all smaller than 40%, and it can thus be regarded that there is no severe common method bias.

Table 7. Variance interpretation frequency.

Table of Variance Interpretation Frequency									
Factor No.	Characteristic Root			Variance Interpretation Frequency before Rotation			Variance Interpretation Frequency after Rotation		
	Characteristic Root	Variance Interpretation Frequency %	Accumulation %	Characteristic Root	Variance Interpretation Frequency%	Accumulation %	Characteristic Root	Interpretation Frequency %	Accumulation %
1	5.230	34.870	34.870	5.230	34.870	34.870	4.352	29.014	29.014
2	1.587	10.582	45.452	1.587	10.582	45.452	1.645	10.965	39.979
3	1.226	8.175	53.626	1.226	8.175	53.626	1.617	10.780	50.759
4	1.029	6.861	60.487	1.029	6.861	60.487	1.459	9.728	60.487
5	0.778	5.188	65.675	-	-	-	-	-	-
6	0.767	5.116	70.791	-	-	-	-	-	-
7	0.693	4.620	75.411	-	-	-	-	-	-
8	0.616	4.107	79.519	-	-	-	-	-	-
9	0.605	4.035	83.554	-	-	-	-	-	-
10	0.525	3.498	87.052	-	-	-	-	-	-
11	0.493	3.284	90.336	-	-	-	-	-	-
12	0.462	3.081	93.417	-	-	-	-	-	-
13	0.361	2.404	95.821	-	-	-	-	-	-
14	0.319	2.128	97.949	-	-	-	-	-	-
15	0.308	2.051	100.000	-	-	-	-	-	-

The research data applied the varimax for rotation so as to determine the corresponding relations between factors and research items (Table 8). The above table indicates the factor information extraction of the research items and the corresponding relations between the factors and the research items. The above table shows that the communality values of all the research items are higher than 0.4, meaning that the strong relevance between the research items and the factors and the factors can effectively extract the information.

3.2.3. Fitting Analysis of Structural Equation Model

Modeling analysis was performed for four latent variables and 15 observational variables according to the framework of the structural equation model of the factor of investigation into the settlement space environment along China's Grand Canal. The model was repeatedly modified until the indexes of correlation of the governing degree all met the requirements according to the fit coefficient of the observational model (Table 9).

Table 8. Factor load coefficients after rotation.

Name	Factor Load Coefficient				Common Degrees Communality
	Factor 1	Factor 2	Factor 3	Factor 4	
A1 Residential building space	0.804	0.076	−0.013	0.058	0.655
A2 Public activity space	0.763	0.075	0.109	0.082	0.606
A3 Commercial service space	0.734	0.072	0.254	0.054	0.611
A4 Cultural service space	0.800	0.053	0.018	0.090	0.651
A5 Education service space	0.617	0.087	0.279	0.318	0.567
A6 Medical service space	0.428	0.062	0.364	0.341	0.435
A7 Canal system space	0.799	0.055	0.121	0.083	0.663
A8 Greening ecological space	0.579	0.013	0.129	0.291	0.436
B1 Industrial production space	0.060	0.794	0.077	0.137	0.659
B2 Agricultural production space	0.057	0.810	0.081	−0.249	0.728
B3 The situation of working out of the village	0.128	0.565	−0.247	0.325	0.503
C1 Traffic service space	0.431	0.025	0.700	0.052	0.679
C2 Traffic congestion	0.032	−0.016	0.836	0.108	0.712
D1 Historic space	0.441	0.062	−0.037	0.540	0.492
D2 Historical and cultural cognition	0.064	0.018	0.187	0.798	0.676

Table 9. Fitting coefficients of the structural equation model.

Index	Fitting the Standard	Simulate the Fitting Values	Index	Fitting the Standard	Simulate the Fitting Values
CMIN/DF	1 < CMIN/DF < 3	2.817	TLI	>0.9	0.969
RMSEA	<0.05 (adaptation is good) <0.08 (adaptation is reasonable)	0.042	CFI	>0.9	0.980
			PGFI	>0.5	0.545
IFI	IFI > 0.9	0.980	PNFI	>0.5	0.619

3.3. Analysis of Structural Equation Model

3.3.1. Relationship of Measurement Expression of the Structural Equation Model

For the ecological Factor 1 of life, the standardized load factor coefficients of the observational variables were A8 > A4 > A5 > A3 > A1 > A2 > A8 > A6, from top to bottom. The measurement result shows (Table 10) that (1) the residents attached more importance to evaluating the canal river system. According to the investigation and interview, China's Grand Canal was the mother river between the space of settlements on both banks, nourishing the ancestors for generations. With the vicissitudes in China's Grand Canal, the residents had more expectations for the transforming and upgrading of the Canal. Moreover, (2) the standardized load coefficients of the space for cultural services, educational services, commercial services, residential buildings and public activities were balanced, indicating that the comprehensive perception of the residents for the factors of ecology of life in the rural settlements along China's Grand Canal focused on the improvement of cultural, education and commercial facilities as well as residential buildings and space for public activities.

For ecological Factor 2 of production, the standardized load coefficient of space for industrial production was 0.730 and that of space for agricultural production was 0.613, indicating that the local residents paid more attention to the space for heavy industrial production in considering the ecological factor of production. According to the investigation, interview and related data, (1) the agricultural production in the settlement space in the Wuqing District and the Jinghai District could basically meet people's requirements for daily life, while that in the Beichen District and the Xiqing District in the suburbs barely could or could not. (2) With the development of urbanization, the rural settlement in the suburbs took the lead in completing industrial transformation. Therefore, the residents preferred to choose the space for industrial production.

Table 10. Relationship of measurement expression of structural equation model.

Measure Expression Relation Summary Table							
X	→	**Y**	**Non-Standardized Load Factor**	***SE***	***z***	***p***	**Normalized Load Factor**
A1 Residential building space	→	Factor 1	1.000	-	-	-	0.742
A2 Public activity space	→	Factor 1	0.989	0.045	21.818	0.000	0.732
A3 Commercial service space	→	Factor 1	1.007	0.045	22.174	0.000	0.746
A4 Cultural service space	→	Factor 1	1.034	0.038	27.504	0.000	0.766
A5 Education service space	→	Factor 1	1.031	0.047	21.961	0.000	0.764
A6 Medical service space	→	Factor 1	0.823	0.046	17.923	0.000	0.610
A7 Canal system space	→	Factor 1	1.094	0.042	25.983	0.000	0.811
A8 Greening ecological space	→	Factor 1	0.862	0.045	19.243	0.000	0.638
B1 Industrial production space	→	Factor 2	1.000	-	-	-	0.730
B2 Agricultural production space	→	Factor 2	0.841	0.078	10.725	0.000	0.613
B3 The situation of working out of the village	→	Factor 2	0.622	0.063	9.879	0.000	0.454
C1 Traffic service space	→	Factor 3	1.000	-	-	-	0.958
C2 Traffic congestion	→	Factor 3	0.501	0.049	10.322	0.000	0.480
D1 Historic space	→	Factor 4	1.000	-	-	-	0.665
D2 Historical and cultural cognition	→	Factor 4	0.636	0.061	10.343	0.000	0.424

Notes: → Indicates the measurement relationship.

For Factor 3 of accessibility, the standardized load coefficient of the space for transportation service was 0.958 and that of traffic congestion was 0.480, exhibiting that the residents most valued the quality of and satisfaction with the space for transportation services among the factors of accessibility. The investigation result shows that the worksite had a correlation with the evaluation of the space for transportation service. The residents working near the local area and the jobless residents felt quite satisfied with the transportation services in the settlements for convenience, while those who worked in Tianjin proper or other cities or towns thought the spatial development for transportation service was relatively backward, and their concerned evaluation was not high.

For Factor 4 of social culture, the standardized load coefficient of the space of historical heritage was 0.665 and that of the perception of the history and culture of China's Grand Canal was 0.424, demonstrating that the residents prioritized the satisfaction with the space of historical heritage in considering the factor of social culture. By analyzing the questionnaire, we can know that, as the material carrier of social culture, the cultural space for historical heritage could arouse the residents' feelings and resonance more, and the residents attached more importance to the on-site cultural elements such as temples, wharves, guild halls and memorial archways.

3.3.2. Analysis Results

The structural equation model usually applies a standardized path coefficient value. If conspicuousness arises, it shows the conspicuous influence/measurement relationship. Conversely, it means there is no influence/measurement relationship. The standardized path coefficient can measure the relevance of the two variants, that is, the degree of influence. In the case of conspicuousness, the influence of the large standardized path coefficient is great.

The Table 11 and Figure 4 indicate that (1) when ecological Factor 1 of life exerted influence on ecological Factor 2 of production, the value of standardized path coefficient was 0.344 > 0, and the significance of the path was 0.01 ($z = 8.212$, $p = 0.000 < 0.01$), implying that Factor 1 exerted a remarkably positive influence on Factor 2.

Table 11. Regression coefficients of structural equation model.

Model Regression Coefficient Summary Table							
X	→	**Y**	**The Non-Normalized Path Coefficient**	***SE***	***z***	***p***	**Normalized Path Coefficient**
Factor 1	→	Factor 2	0.339	0.041	8.212	0.000	0.344
Factor 1	→	Factor 3	0.701	0.062	11.312	0.000	0.543
Factor 3	→	Factor 1	0.101	0.042	2.413	0.016	0.131
Factor 4	→	Factor 1	0.853	0.092	9.247	0.000	0.765

Notes: → Indicates the path influence relationship.

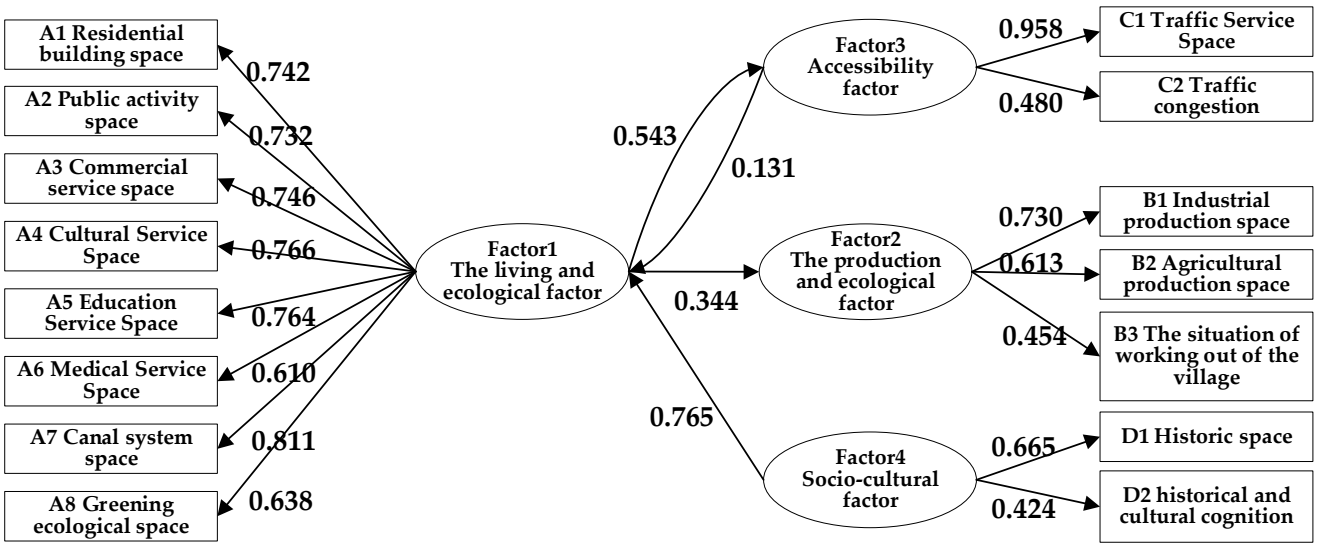

Figure 4. Structural equation model results.

(2) When ecological Factor 1 of life exerted influence on ecological Factor 3 of accessibility, the value of standardized path coefficient was 0.543 > 0 and the significance of the path was 0.01 (z = 11.312, p = 0.000 < 0.01); when Factor 3 had influence on Factor 1, the value of standardized path coefficient was 0.131 > 0 and the significance of the path was 0.05 (z = 2.413, p = 0.016 < 0.05), indicating that Factor 1 and Factor 3 had a relation of mutual influence.

(3) When Factor 4 of social culture exercised influence on Factor 1, the value of standardized path coefficient was 0.765 > 0 and the significance of the path was 0.01 (z = 9.247, p = 0.000 < 0.01), showing that Factor 4 had a positive influence on Factor 1.

Moreover, the standardized path coefficient indicates that Factor 4 (the factor of social culture) exerts the greatest influence on Factor 1 (the factor of ecology of life), followed by the influence of Factor 1 (life) on Factor 3 (the factor of accessibility), then that of Factor 1 (life) on Factor 2 (the factor of ecology of production), and finally, that of Factor 3 (accessibility) on Factor 1 (life).

4. Discussion

The investigation of the settlements along China's Grand Canal from the perspective of resident perception is valuable for mastering the current conservation and inheritance of the cultural heritage of China's Grand Canal. Cheng, Z.F. et al. thought that different village residents had different cultural perceptions of China's Grand Canal Beijing Section, and spatial expressions of the Canal culture should be enhanced [17]. The research entailed an empirical analysis of the interrelations of the investigation factors of the spatial environment of the settlements along China's Grand Canal Tianjin Section, employing the structural equation model to analyze the inherent laws influencing the changes in the status of the settlement spatial environment. The factors of investigation into the settlement space

environment along China's Grand Canal typically comprised the factors of ecology of life, ecology of production, accessibility and social culture. Based on the 1033 completed questionnaires from 44 typical villages along China's Grand Canal Tianjin Section, we analyzed the current problems of the settlement space environment along the Canal and revealed the inherent relations between the factors of ecology of life, ecology of production, accessibility and social culture through the approach of the structural equation model. The research established the SEM model of the settlement space environment. The measurement data validity was quite high through validity and reliability tests. The factor test analysis showed that the factor of the model did not have the problem of common method bias. Hence, the reliability of the model was high. The model further enriches the type and composition of the investigation into the settlement space environment, expands the cognitive perspective of the current settlement space along the Canal and provides a new research thought for the protection and updating of the settlement space environment. The model analysis results show that the factor of ecology of life exerted a positive influence on the factor of ecology of production and the factor of accessibility. The factor of accessibility also exerted a positive influence on the factor of ecology of life, indicating that the factor of ecology of life, as the core element, was an important carrier for the residents to perceive the quality of life. The factor of the ecology of production, as the driving element, was an important source of the residents' stable life. The factor of accessibility, as the guarantee element, was the basic condition for the residents' daily travel. Meanwhile, the factor of social culture, a supporting element of the settlement space environment along the Canal, was the core part boosting the residents' confidence in culture.

The research results indicate that the evaluation result of the ecological factor of production was the lowest because some settlement space suffered from low productivity, backward modes of operation, low rural income, slow industrial development, migrant work of middle-aged and young rural people in cities and less engagement in traditional agriculture due to rapid urbanization. The general evaluation of the factor of social culture was moderate, the residents universally lacked knowledge of China's Grand Canal culture and the history of the settlement along the Canal, and the space of historical and cultural heritage lacked effective conservation and utilization. As to the ecological factor of life, some residential buildings along the Canal suffered the problems such as long-term disrepair, poor quality, low satisfaction of the residents, incomplete public facilities for culture, education and medical care, pollution and low utilization rate of the canal river system. The factor of accessibility suffered problems such as incomplete road facilities, simple structure of underlying surface and narrow, uneven roads.

The resource investigation, characteristic extraction and research on conservation and utilization of the settlement space environment along China's Grand Canal in the new era can effectively solve problems such as blind, unbalanced and insufficient development of the settlement space environment along the Canal, take roots in the rural culture and supplement the cultural genes of China's Grand Canal so as to fundamentally boost the cultural confidence of the residents. The basic theory and empirical analysis of the research exhibit that the quality of the space environment can be improved in four dimensions, namely, the ecological features of life, ecological features of production, accessibility and social culture. Follow-up research can be carried out in terms of industrial restructuring, historical and cultural conservation and livable environment improvement to fuel the conservation and rejuvenation of the settlements along China's Grand Canal.

5. Conclusions

The settlement space environment along China's Grand Canal, a core area of the canal heritage, bears the life wisdom and cultural footprints of generations of ancestors. The inheritance, protection and development of the settlement space along the Canal have profound influence on boosting cultural confidence and the quality of cultural belt construction and rural rejuvenation along China's Grand Canal. Here, we set up the framework of factors of investigation into the settlement space environment along the

Grand Canal, took 44 representative settlements along China's Grand Canal Tianjin Section and offered fundamental reference for characteristic extraction, evaluation and optimized development of the space environment there. The ecological factor of life had a positive influence on that of production, with a path coefficient of 0.344. The ecological factor of life and the factor of accessibility had a positive influence. The former exerted the most obvious influence on the latter, with a path coefficient of 0.534, and the path coefficient of the latter upon the former was 0.131. The factor of social culture had positive influence on the ecological factor of life, with a path coefficient of 0.765.

With China's Grand Canal Tianjin Section as an example, we set up the model of factors of investigation into the settlement space environment along the Canal, expounded the inherent law of the factors of space and initially clarified the status quo of the environment there. In selecting the observational variables, more considerations were given to the questions on the ecology of life and production in the settlements, more easily understandable and perceptible for the residents. Meanwhile, limited by data measurability, the questions relating to the factor of social culture were comparatively few—for instance, data collection was realized on the specific contents of rural cultural customs and historical heritage through some categorized questions. Therefore, the factor of model needs further improvement, contributing to enhancing the viability of analysis.

The research conclusions are valuable for probing and analyzing the status quo and inherent laws of the settlement space along Tianjin Section with a macroscopic holistic vision. We suggest that the research results are applied in the investigation and research of the settlement space environment of other areas to help reveal the status quo of the settlement space environment and thus provide references for the protection, development and spatial optimization of the settlement space environment along the canals of China and even around the world. In the future, the research on the settlement space environment along the Canal should give solutions and countermeasures from four dimensions, namely, the ecology of life, the ecology of production, accessibility and social culture, and provide an overall scientific basis for improving the overall quality of the settlement space environment along the Canal.

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