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Spatial integration of oasis city group around the western margins of the Tarim Basin

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Cover Page Footnote

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Spatial integration of oasis city group around the western margins of the Tarim Basin

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Abstract: In this paper, the oasis cities in Kashgar Prefecture and Kizilsu Kirgiz Autonomous Prefecture are taken as an example, through the factor analysis, spatial attraction interaction model and location quotient methods, urban hierarchy system, the intensity of urban economic ties, economic subordination degree, and structure of city functions were analyzed. The results indicated: (1) The urban hierarchy system takes Kashgar city as the main center, Artux city, Yarkant county and Maralbexi county as the sub-centers; (2) The intensity of economic ties among Kashgar city and each county is much higher than others. The interaction of Kashgar city, Shufu county and Shule county are the strongest, and the economic ties of Yarkant, Kagilik, Poskam counties are relatively close; All cities in the study area are economically subordinate to Kashgar city. (3) Three cities of Kashgar city, Shufu county and Shule county should connect strongly, with Kashgar city as the core. The cities and towns along the Southern Xinjiang Railway and along National Road 315 should be regarded as two strips, and the two city strips along the border, and the city strip along Provincial Road 215 should be treated as three axes. The ring structure strategy of "core ring, closer ring and radiated ring" was proposed. (4) It was proposed to build Kashgar city group in the north, and Yarkant city group in the south, Maralbexi city group in the southeast, and Taxkorgan border city group with four inner groups' development strategy.

Keywords: Tarim Basin; oasis city; city group; spatial integration

1 Introduction

'City group' refers to a group of a certain number of cities with different scale, level, nature and type in a specific geographical area (Wang, 2001). From the urbanization level and economic development degree, a 'city group' can be understood as a transition phase in the evolution of city group structure into a monomer city, city group, city agglomeration (city groups), megalopolis area in an orderly development process (Wang, 2008). The integration of city groups refers to the cooperation, competition and control framework from the spatial perspective based on the status of the development of spatial research. It is necessary to analyze the potential and limitations for spatial development, and future spatial development trend (Yang, 2004; Song, 2006). The integration can strengthen the functional complementation among the cities**,** coordinate regional development, and improve overall regional competitive capacity. The concept of Central Place Theory was proposed by Christaller (Walter, 1966), and regional systems of city groups was first mentioned in his theory. Also city spatial structure, evolution characteristics, spatial flow of economic ties, city interaction model and development mechanism have been studied (Wallis, 1994; Gustavo, 1999; Tomoya, 1999; Frisken, 2001), and such research has played an important role in the development of understanding of city groups and urban groups.

Oasis cities in arid areas are the core in the development of arid areas. But compared with inland cities, the scale of oasis cities was small because of dispersion, vulnerability, limitations on water availability, and access to the oases' physical environments. The connection between cities is not strong. Cities are distributed along rivers and traffic corridors. The expansion of population and land use are restricted by the oases' geographical scope and natural resources. Inter-city ties are a foundation, but conflicts with the urban industrialization. Integration of urban space provides the means for the coordination of urban

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development, alleviation of differences between the oasis and the city and realization of city transformation in arid areas. Presently, scholars pay more attention to the Xinjiang oasis city at the scale, function, layout and the development mechanism of individual oasis city systems at different spatial scales, and focus less on integration into city groups (Fang, 1991; Fang, 1993; Zhang, 1998; Li, 1999). In this paper, our aims are to analyze the development status of oasis cities, reveal the inter-city interactions, spatial integration of city groups, and put forward an approach for coordinated regional development.

2 Study area

The selected oasis cities are located in the western margin of the Tarim Basin, including one city and 11 counties in Kashgar Prefecture, and one city and two counties in Kizilsu Kirgiz Autonomous Prefecture. In 2008, the total population of the study area was 4,030,000 and the urbanization level was 20.26%. The annual gross domestic product was 18.2 billion, which accounted for 26.10% of the GDP of southern Xinjiang. Although secondary industrial development has been slow and industrial structure is 41:20:39, the economic ties between Kashgar city and adjacent cities are becoming stronger with the rapid development of the economy, and the trend of spatial integration is very clear.

3 Methods

3.1 Data collection

Data were collected from Xinjiang Statistic Yearbook (2008), Kashgar Statistic Yearbook (2008), Kizilsu Kirgiz Autonomous Prefecture Statistic Yearbook (2008), and the data of distance between cities were measured by ArcGis.

3.2 Analysis method of city hierarchy system

Integrated index, which can embody the comprehensive strength and central position within a city system, was used to classify and grade 15 cities. The assessment was based on 5 aspects, which were (1) city size and scale, (2) economy, (3) infrastructure, (4) socio-economic conditions and (5) environmental conditions (Fig. 2). Factor analysis was used to calculate city 'centricity'.

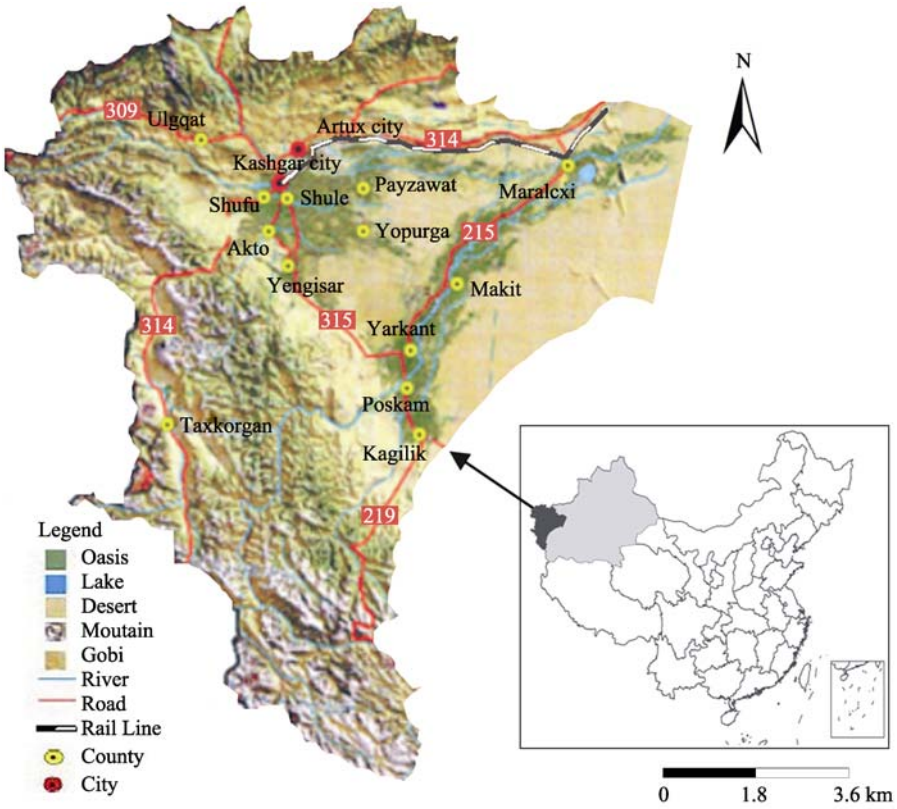

Fig. 1 Location of the study area

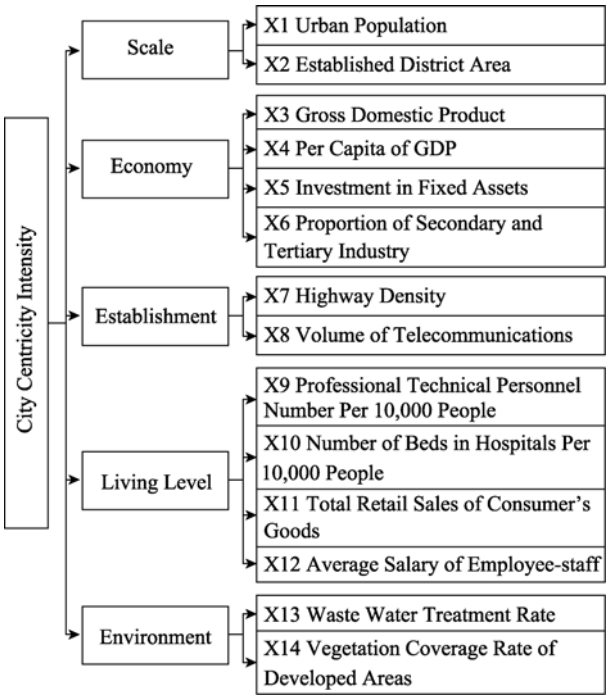

Fig. 2 Appraisal target system of city centricity intensity

3.3 Model of economic linkage intensity and economic subordination

The 'Gravity model' of spatial interaction was used to measure and calculate the economic linkage intensity and economic subordination degree among cities (Wang, 1996; Li, 2001; Miao, 2006).

$$R_{ij} = (\sqrt{P_i G_i} \times \sqrt{P_j G_j}) / D_{ij}^2, F_{ij} = R_{ij} / \sum_{j=1}^{n} R_{ij}. \quad (1)$$

Where, R_{ij} indicates economic linkage intensity between two cities; F_{ij} indicates the ratio of economic linkage intensity accounted for in the total regional economic linkage intensity, or economic linkage subordination degree. P_i and P_j indicate non-agricultural population in each city; G_i and G_j indicate gross domestic products, and D_{ij} indicates the distance between the two cities.

$E = \sum_{j=1}^{n} F_{ij}$ indicates the economic subordination degree of other cities on *i* city.

3.4 Analysis method of function structure

Eighteen urban industries, (i.e. not agriculture, forestry, animal husbandry, fishery or other rural industries) were selected and integrated into 7 functions in the analysis of economic foundation (Zhang, 2008). The principal functions and non-essential functions of each city were analyzed using the concentration location quotient method (Eq. 2 and Table 1).

$$P_i = (M_i / \sum_i M_i) / (M'_i / \sum_i M'_i). \quad (2)$$

Where, P_i is the location quotient of *i* functions to the greater region, M_i is the industry level of the *i* function as part of all city functions, M'_i stands for the industry level of the greater region.

4 Results and discussion

4.1 Analysis of city group

4.1.1 Hierarchy system of cities

Fifteen cities can be divided into three grades by city centricity (Table 1). Kashgar city is the central city in Kashgar Prefecture with the most powerful integrated development strength, and it is the core of the city group in this city group system. Artux city, Yarkant and Maralbexi counties as the regional sub-centers only account for 20% of the total cities in the study area. Eleven cities such as Kagilik, Yopurga as local city centers account for 73.3% of the total number of cities.

4.1.2 Economic linkage intensity

According to Eq. 1, mutual economic linkage intensity among the cities is shown in Fig. 3. The economic linkage intensity among Kashgar city, Shule and Shufu is the strongest. The economic linkage intensity was calculated to be 98,456 between Kashgar city and Shule, 31,619 between Kashgar city and Shufu, and 13,472 between Shufu and Shule. This showed the citys' spatial interaction center as Kashgar city–Shufu–Shule, with Artux city, Payzawat, Yopurga, Yengisar, and Akto as sub-centers. The economic

Table 1 Hierarchy classification of city groups in 2007

Centricity intensity	Grade	Grade item	City (centricity intensity value)
>1	I	Region center	Kashgar city (1.85)
0–1	II	Region sub-center	Yarkant (0.61), Artux city (0.52), Maralbexi (0.15)
<0	III	Local center city	Kagilik(–0.03), Yopurga(–0.06), Taxkorgan(–0.10), Ulugqat(–0.17), Payzawat(–0.29) Shule(–0.35), Makit (–0. 40), Poskam (–0.43), Akto(–0.44), Shufu(–0.45), Yengisar (–0.48)

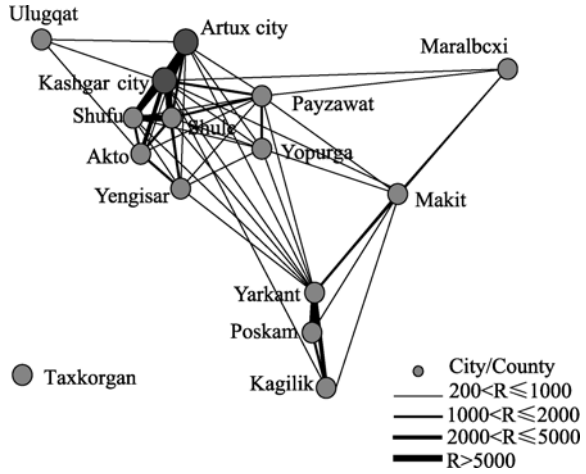

Fig. 3 Economic linkage intensity among city group in 2007
Economic linkage intensity R≤200 doesn't exist in this figure

linkage intensity among Poskam, Yarkant and Kagilik is high. Taxkorgan and Maralbexi are farther from other cities, so the economic linkage intensity is low.

4.1.3 Economic subordination degree

The degree of economic subordination between cities is shown in Fig. 4. Two peak values occurred near Kashgar and Yarkant, that is, the concentrated impact region of Kashgar city–Shufu–Shule as the core, and Yarkant–Poskam as a sub-center. Each city has a close economic exchange with these cities in their two sub-regions, with a more concentrated flow of economic activity and commodity towards the city groups.

From the viewpoint of individual cities, the economic subordination degrees of Shule to Kashgar city (0.84), Shufu to Kashgar city (0.63), Kashgar city to Shule (0.71), Poskam to Yarkant (0.70), Artux city to Kashgar city (0.50), and Yarkant to Poskam (0.57) are all greater than 0.5. They have clear subordination relationships. As shown in Table 3, the highest subordination degree is to Kashgar city where the E value reaches 3.77. Shule lies in the south-east corridor of Kashgar city and its *E* value (2.13) is second to Kashgar. Yarkant as the economic center of the Yarkant River Valley has a significant economic interaction with adjacent cities, having an *E* value of 2.11. The *E* values of Taxkorgan and Ulugqat are low, and their economy impact on other cities in the study area is not obvious.

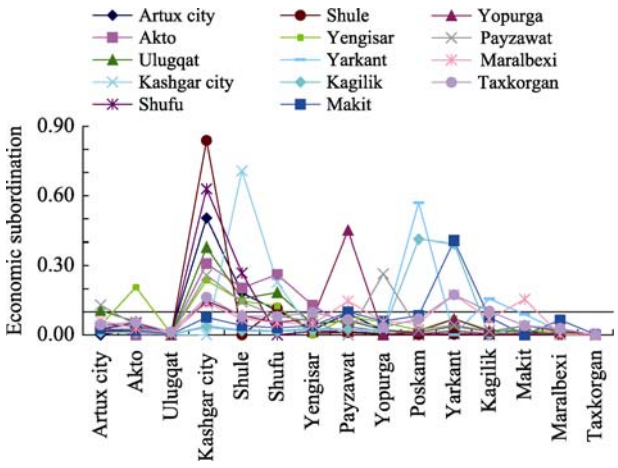

Fig. 4 Economic subordination between cities in 2007

Table 3 Economic subordination degree of city group to the cities

County/city	*E*-value	County/city	*E*-value
Artux city	0.60	Yarkant	2.11
Akto	0.59	Kagilik	0.69
Ulugqat	0.06	Makit	0.48
Kashgar city	3.77	Yopurga	0.58
Shufu	1.36	Payzawat	0.13
Shule	2.13	Maralbexi	0.21
Yengisar	0.60	Taxkorgan	0.02
Poskam	1.27		

4.1.4 Function structure

The results show that the degree of economic specialization by the cities in the study area is low, and the city division is unclear. Only Kashgar and Artux are comprehensive cities. The principal functions of Kashgar city and Artux city include commerce, science and technology, education, culture, health, transport industry, state organs and service industry. Their city functions are more comprehensive than those of other counties. The principal function of Poskam is industry, while the principal function of Maralbexi and Yarkant is commerce. The principal functions of the other cities are not obvious.

4.2 Spatial integration analysis of city group

4.2.1 Environmental structure analysis of spatial integration

From the results of economic linkage intensity (Fig. 3), it can be seen that the economic linkage intensity among 6 counties (cities) in the northwestern of the region of Kashgar Prefecture and 3 counties (cities) in

the Kizilsu Kirgiz Autonomous Prefecture is high. Also, the geometry of spatial layout is approximately hexagonal around Kashgar (Fig. 5), which is consistent with Christaller's Central Place Theory (Walter, 1966). Kashgar city, located in the center of the hexagon, assumes the role of gathering and spreading. If the locations of Kashgar and the surrounding eight counties and cities is slightly adjusted, the geometric map of these nine counties and cities can be approximated to be included within an equilateral hexagon (Fig. 6). Kashgar city is located at the geometric center of the equilateral hexagon, while Artux city, Payzawat, Yopurga, Yengisar, Akto, Ulugqat are located at the apexes of the hexagon. In theory, Kashgar city, as the economic center, should perform the function of full radiation and distribution to these six adjacent centers. Kashgar city has a lack of space for development; Shule and Shufu close to Kashgar, have the closest economic linkage with Kashgar city. From the perspective of central place theory, Kashgar city, Shufu and Shule should be integrated into one strong core. This core possesses the spatial structure that could bring distinct benefits, reduce administrative costs, and improve efficiency and effectiveness of space utilization and the clustering effect (Fang, 2008).

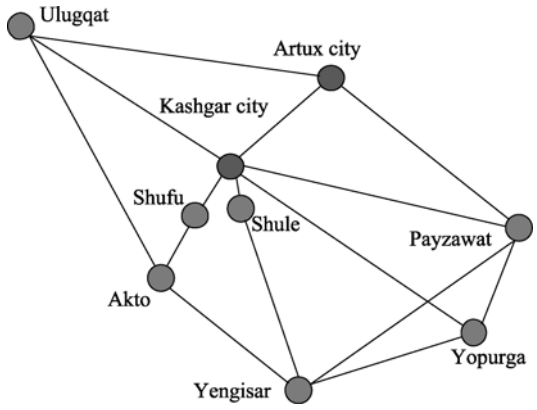

Fig. 5 Spatial organizing morphology of Kashgar and other cities

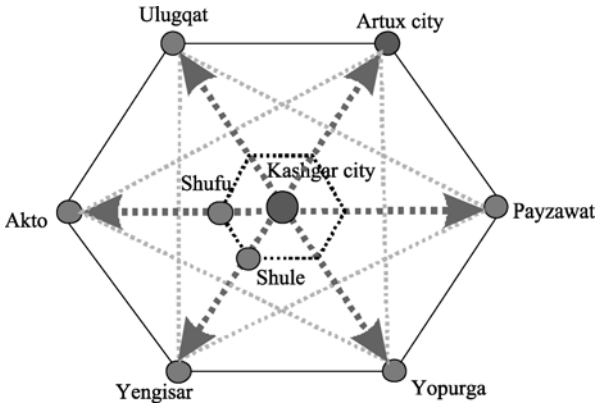

Fig. 6 Abstract spatial morphology of Kashgar and other cities

4.2.2 Pole-axle structure analysis of spatial integration

Major cities and towns in city groups tend to be distributed along transport corridors, forming typical pole-axle structures. According to the actual development of cities in this region and the existing main transportation network (the Southern Xinjiang Railway, National Road 315, National Road 314 and Provincial Road 215) and the parts of the network now under-construction(China–Kyrgyzstan–Uzbekistanrail way and China–Pakistan railway) a Pole-axis development model is forming, with “one core, two strips, and three axis” (Fig. 7).

The one core is Kashgar city with regional financial, commercial, logistic, technology, information and modern manufacturing by high technology industries. Due to its lack of development space, a Greater Kashkar should include Shufu and Shule to strengthen the central role of Kashgar city. This will enhance the radiation and leading role of the regional growth pole.

‘Two strips’ refer to the Maralbexi–Payzawat–Artux–Kashgar strip along the Southern Xinjiang Railway and the Kashgar–Shule–Yengisar–Yarkant–Poskam–Kagilik strip along National Road 315. These two city strips are important components of the southern Xinjiang railway city strip in Xinjiang’s “one ring and three strips” development strategy. They are also the main development axes for the city group. The former strip is the contact channel for this regional city group with Bayangol Mongolia Autonomous Prefecture and Aksu Prefecture in southern Xinjiang. It is also the entrance for the East–West alliance and the exit for East-West trade, which has an extremely important status in future development. The latter is not only an important transportation corridor for Kashgar Prefecture, but a main channel of economic exchange between the city group and the Hotan Prefecture. In the future the influence of the city group could radiate

and lead the regional development of Hotan.

The ‘three axes’ refer to (1) Maralbexi–Makit–Yarkant–Taxkorgan development axis along Provincial Road 213, (2) the external contact axis along Kashgar city–Shufu–Akto–Taxkorgan–Khunjerab port and Karasu port (to West Asia and South Asia) and (3) the external contact axis Kashgar city–Ulugqat–Turugart port (to Central Asia). In the first axis, economic linkage intensity between Yarkant and Taxkorgan is low. It is necessary to strengthen road construction and regional contacts providing the trade channel for Yarkant, Poskam and Kagilik to South Asia and West Asia. The latter two axes are for international economics and trade. They are important components of the Xinjiang border cities strip, and also two important trade routes to set up trade and tourism for the city group towards Central Asia and South Asia.

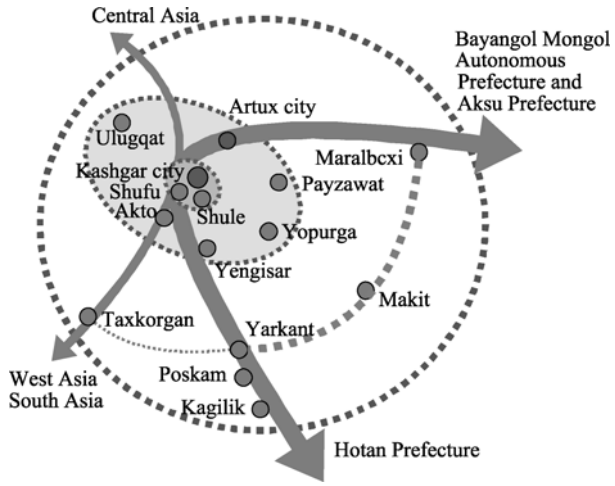

Fig. 7 Pole-axes structure and ring structure of the city group

4.2.3 Ring structure analysis of spatial integration

In accordance with the intensity of city interaction in the Kashgar Prefecture, the ring space integrated structure of “core ring, close ring and radiating ring” has basically formed (Fig. 7). The core ring includes Kashgar city, Shufu and Shule with a radius of 20 km, and an economic ring of half an hour. This is the most affected region of Kashgar city, and also the most active economic region. The close ring includes Artux city, Payzawat, Yopurga, Yengisar, Ulugqat and Akto, with a radius of 40–85 km, and a one-hour economic ring. The cities in this economic ring are smaller with simple functional structure and they have close economy interaction with the core city, but weaker economic linkage intensities among each other. The radiating ring, includes cities of Maralbexi, Makit, Yarkant, Poskam, Kagilik and Taxkorgan , as well as Hotan city, Lop, Guma and Karakax in Hotan Prefecture, which has a 2–3 hour economic ring. The main aim in future is to strengthen the integrated development and economic leadership of the core ring, and increase economic cooperation and transport construction. Outward expansion of the close ring, will improve trade to Central Asia (Turugart port) in north, towards Hotan Prefecture in the south, and to West Asia and South Asia (Kurasu port and Khunjerab port) in the west. In future the preferential development of the three prefectures in southern Xinjiang is proposed to become the fulcrum for the opening up strategy in western Xinjiang.

4.2.4 Group structure analysis of spatial integration

According to the city hierarchy system (Table 2), inter-city interaction and economic contacts (Fig. 3) and city function divisions (See 4.1.4), the city group can be divided into four, so as to achieve a better spatial region integration.

Kashgar city group in the north: includes 2 cities, 7 counties and 100 towns. It is formed around Kashgar city as the core, with Artux city, Shule, Shufu, Payzawat, Yopurga, Yengisar, Akto, and Ulugqat as the sub-centers, and 100 towns as the nodes for trade, tourism and transport.

Yarkant city group in the south: includes 4 counties and 67 towns. It is formed around Yarkant as the regional center, with Kagilik, Makit and Poskam as the sub-centers, and 67 towns as the nodes for industry, petrochemical industry and trade.

Maralbexi city groups in the east: includes one county and 12 towns. Taking Maralbexi as the center, its radiated areas include 12 towns as well as parts of the neighboring counties. It should develop as the material distribution center and trade center for the eastern Kashgar region.

Taxkorgan border city groups in the southwest: includes one county and 13 towns. Taking Taxkorgan as the center, it should become an economic zone with integration of border trade, warehousing and tourism based on the traffic corridor.

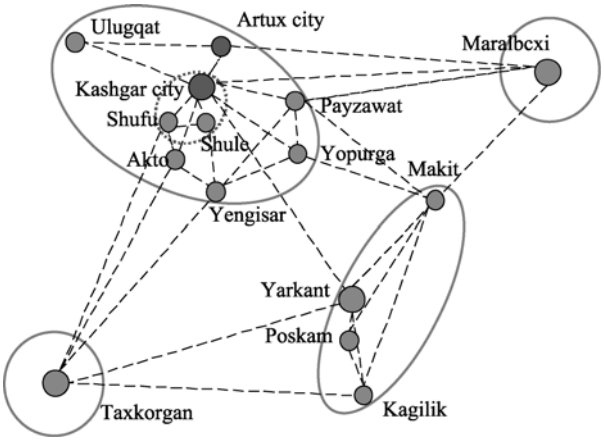

Fig. 8 Internal group structure of the city groups

5 Conclusions

Based on the analysis above, this paper presents an approach to the development of a group of cities in the western Tarim Basin, confirms its overall orientation in future development, and presents a strategy which can promote the coordinated development of all cities in the group. The strategies are: (1) Based on the recognition of Pole-Axes structures, including “One Core”, “Two Belts” and “Three Axes”, Kashigar city, Shufu and Shule should be integrated to form a strong center, two belts are the transport corridors along the Southern Xinjiang railway and National Road 315, and the three axes are the two border city belts and city belt along Provincial Road 215; (2) The circling structures, involving “Core Ring”, “Close Ring” and “Radiating Ring”; (3) A subdivision of the cities’ group structure into four smaller groups in order to improve coordination between and within these geographical groups.

The paper has discussed objective strategy and direction for urban development based on actual data for urban and economic development in the Kashgar Prefecture and Kizilsu Kirgiz Autonomous Prefecture. The role of economic development in spatial integration is emphasized, but in fact, Kashgar city is the executive administration center for Kashgar Prefecture. The local government performed its administrative center functions, and continuously strives to strengthen the city's economic and cultural functions, thus making Kashgar city the center for concentrated economic activity. It is really a city of both top-down political decisions and largely ‘free market’ business decisions. In the existing regional administrative division, the city’s spatial integration was controlled by the government (Yuan, 2006). So the study has some limitations, especially in less developed oasis cities in arid areas, where the remoteness of the oases restrict economic ties and regional integration among the cities. Research into guiding and promoting the free flow of regional elements, implementing macroscopic development strategies, inter-city industry co-ordination and cooperation whilst optimizing the allocation and management of natural resources needs further study.

Acknowledgements

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References

Fang C L. Research on forming and developing mechanism of oasis model town system in Gansu province. Arid Land Geography, 1999, 14(4): 65–69.

Fang C L, Lin X Q. The spatial integration and industrial rationalization organization of Wuhan Urban Agglomeration. Geographical Research, 2008, 27(2): 397–408.

Fang C L, Zhang B. Study on the development and layout of the town system in oasis of Gansu. Journal of Northwest Normal University (Natural Science Edition), 1993, 29(1): 55–60.

Frisken F, Norris D F. Regionalism reconsidered. Journal of Urban Affairs, 2001, 23(5): 467–478.

Gustavo G. Global economy: metropolitan dynamics and urban policies in Mexico. Cities, 1999. 16(3): 149–170.

Li G P, Wang L M, Yang K Z. The measurement and analysis of economic relationship between Shenzhen and Zhujiang Delta. Economic Geography, 2001, 21(1): 33–37.

Li Z G. The spatial scale structure of the city-town system in the arid in Jiuquan-Jiayuguan region. Geographical Research, 1999, 18(1): 87–95.

Liu X L, Fang C L, Wang F Z. Study on spatial combination characteristics and conformity patterns of the central plain city cluster. Geographical Research, 2008, 27(2): 410–420.

Miao C H, Wang H J. On the direction and intensity of urban economic contacts in Henan province. Geographical Research, 2006, 25(2): 222–232.

Song J T, Fang C L, Song D J. Spatial structure stability of urban ag-

glomeration in China. Acta Geographica Sinica, 2006, 61(12): 1312−1325.

Statistics Bureau of Kashgar Prefecture. Kashgar Statistic Yearbook (2008), Kashgar, 2008

Statistics Bureau of Kizilsu Kirgiz Autonomous Prefecture. Kizilsu Kirgiz Autonomous Prefecture Statistic Yearbook (2008), Artux, 2008.

Statistics Bureau of Xinjiang Uygur Autonomous Region. Xinjiang Statistic Yearbook (2008), Beijing: China Statistics Press, 2008.

Tomoya M. A modeling of megalopolis formation: the maturing of city systems. Journal of Urban Economics, 1997, 42(1): 133−157.

Wallis A D. Evolving structures and challenges of metropolitan regions: part of a symposium on the challenge of American renewal. National Civic Review, 1994, 83 (1): 40−53.

Walter C. Central Places in Southern Geography. London: Prentice Hall, 1966.

Wang D Z, Zhuang R X. The preliminary probe into the quantitative analysis of regional economic links: a case study on economic links between Su-Xi-Chang and Shanghai. Scientia Geographica Sinica, 1996, 16(1): 51−57.

Wang F Z, Guo Z F, Liu X L. The structure optimization of the urban system in Zhongyuan region: based on the integrated development of the urban agglomeration. Geographical Research, 2007, 26(4): 637−650.

Wang S J, Wang D, Gao Q. A new urban interrelation pattern—adjacent urban integrate. Scientia Geographica Sinica, 2001, 21(6): 558−563.

Wang S J, Wu C. Definition and analysis of cities group and relevant concepts. Modern Urban Research, 2008, (3): 6−13.

Yang X Z, Yang Y Z, Liu A R. A study on the spatial conformity strategy of central Henan urban agglomeration. Area Research and Development, 2004, 23(5): 33−37.

Zhang X L. Study on Urban Regional System of Xinjiang. Beijing: Chinese Academy of Sciences. 1998: 36−54.

Zhang Y F, Yang D G, Zhang X L. Research on regional structure and spatial fractal characteristics of urban agglomerations at northern slope of Tianshan Mountains. Journal of Desert Research, 2008, 28(4): 795−804.

A brief introduction to Physical Geography of Arid Land in China

A book, **Physical Geography of Arid Land in China**, mainly edited by Prof. Xi CHEN from Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences has been published by Science Press in July of 2010. The book studies the interactions between various physical elements and human factors in the arid land of China. It makes an important step forward in the comprehensive and scientific research on regional geography. By thoroughly reviewing and integrating theoretical research and practical application of physical geography in recent 50 years, the book systematically presents the characteristics, natural resources and their rational utilization in China's arid land.

The book is organized into two sections and twenty chapters. The first section consists of ten chapters and describes in detail the interactions among the various physical elements in the arid land of China. Moreover, the formation and evolution of physical geographic patterns, and the structures and processes of the physical environment are also outlined. The second section consists of ten chapters, in which areal differentiation is described, and a scheme of physical geographic regionalization is put forward. Some rational suggestions and countermeasures are also elaborated on natural resource utilization, environment protection and sustainable social and economic development at sub-regional level.

With plentiful contents and accurate data, this book is rigorous and distinct work, according with many innovative viewpoints and findings. All of these make the book a good reference for scientists, teachers and students who are engaged in research on geography, geology, climatology, hydrology, landscape ecology, agriculture, forestry, environmental protection and management in arid land.