# Thinking About ‘Urban Shrinkage’ based on Spatial Autocorrelation Analysis

*Case Study on Northeast China*

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**ABSTRACT:**

While the phenomenon of population decline and urban growth are contradictory, they are certainly possible that co-exist in some areas. Therefore, it would be inappropriate to define population decline as “shrinkage” or even “degression”. This research takes the northeast of China (the core area of China’s industrial and economic growth) as an example. The data of this research is framed within the period of shrinkage, and population density distribution and accessibility of transportation network are analyzed via ArcGIS. The weight of network spatial matrix is constructed based on the network data of highway transportation. The features and characteristics of the so-called ‘urban shrinkage’ have been summarized. Urban shrinkage in the northeast of China can be interpreted as the migration and re-integration of the population on a wide geographical scale. Therefore, the key to the planning strategy should be shifted from urban renewal and regression to the reasonable layout of urban scale and the rational arrangement of urban and rural spatial structure in the master planning of urban agglomeration. The study discussed the rationality of redefining urban shrinkage and highlighted the vitality of urban agglomeration’s planning. In addition, this study is expected to be referential for the integration of the structure of urban agglomeration and the development of urban function in the future.

**Keywords:** urban shrinkage, spatial analysis, urban agglomeration.

# 1 **Introduction**

In the existing research, The terminology of 'urban shrinkage' has been defined as an issue for future development. Phrases like 'smart shrinkage'[1], 'shrink shrewdly', 'urban renewal', or 'urban regeneration' were frequently mentioned in the improvement of the attractiveness and rejuvenation of the city. These topics may count in the architectural and landscape scopes but are meaningless from a wider perspective. For example, after about 20 years of rapid urbanization and economic development, the population of a certain region in China has gradually decreased since 2010, and it seems to be facing the problem of urban "shrinkage"(Figure 1).

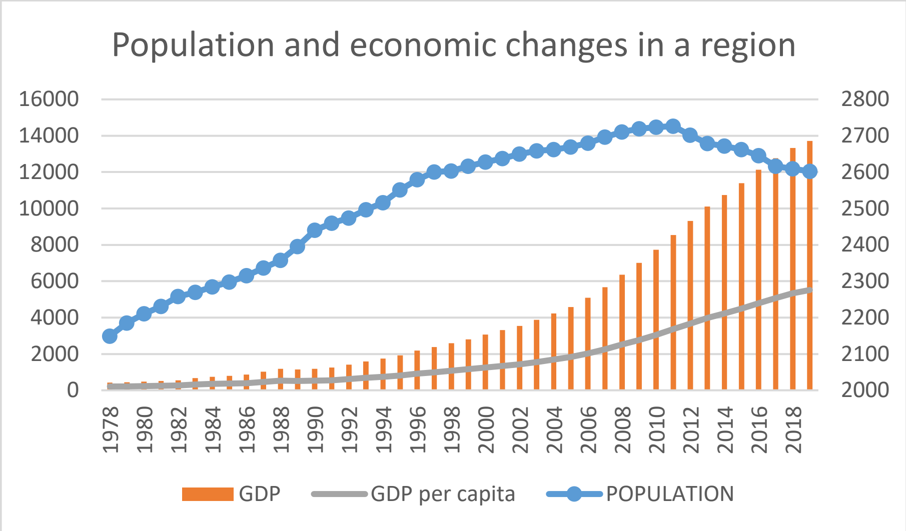



Figure 1 - Population and economic changes in a certain region in China

Figure 1 shows that both the GDP and per capita GDP of the region increased (the statistical indicator here is the Real GDP, which takes inflation into consideration and obtains the results by comparing the 1952 benchmark data as the starting year). The statistics indicate that the overall development of the region is still in a very healthy condition.

According to the relative research[2], the correlation between population and economy usually is highly positive. For instance, Detroit had lost nearly half of its population during 1950-1970 along with an almost 30% decline in its industrial GDP. Therefore, a contradiction arised between the 'negative effect' of urban shrinkage and the 'positive development' of regional reality.

The question below arose that cities are growing with the decrease in population:

1) Whether it is appropriate to call it shrinking? Does the current definition of urban shrinking need to be adjusted?

2) Whether some cities in a special situation were improperly classified as 'urban shrinkage', which should be generalized as a new concept?

3) What features of the new concept would have to be established, and what planning strategy should be applied to respond to it?

The above-mentioned questions are analyzed within a spatial urban context operated in the ArcGIS platform to seek out possible answers.

# 2 Literature Review

## 2.1 Types of 'Urban Shrinkage'

According to the spatial distribution of the population, shrinking cities can be roughly divided into two categories. One is 'perforated' cities represented by European shrinking cities such as Ruhr industrial area. The other is the 'doughnut' city represented by the shrinking cities in North America such as Detroit. The 'perforated' cities' main features are vacant and abandoned buildings or blocks in some areas of the city, which results in the destruction and hollowness of the urban texture. The 'doughnut' one mostly happens in the rust belt area of the northeastern United States in which case the population in the urban center moves to other cities or suburbs in large numbers[3].

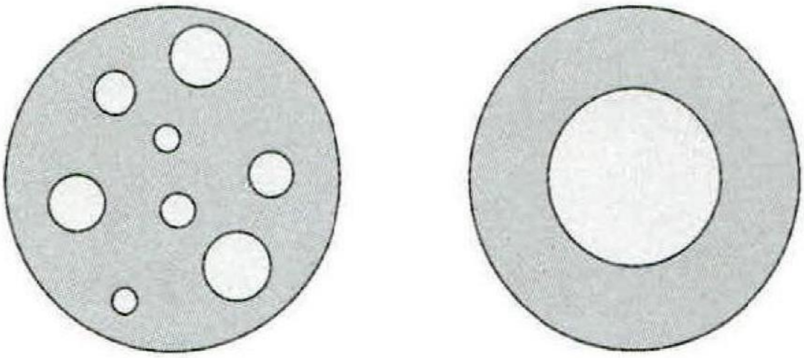


Figure 2 – Illustration of perforated shrinking city and doughnut shrinking city

## 2.2 Causes of the 'Urban Shrinkage'

### 2.2.1 Globalization

Globalization has produced highly competitive "global cities". It has also made many industrial cities unable to prosper permanently in the competitive international environment[4]. Cities rely on single industrial fields and economic sectors are vulnerable to the impact of globalization. The result is an outflow of population[5].

### 2.2.2 Deindustrialization

After many cities complete urbanization through industrialization, the industrial structure will adjust and modify in due course. Business services would replace factories, which means the city's developing priority would shift from the secondary industry to the tertiary industry. The professional skills of the labor force originally engaged in the secondary industry could not meet the demands of employment in the new tertiary industry. This circumstance would lead to a flow of population[6].

### 2.2.3 Suburbanization

Urban shrinkage of cities in North America is caused by suburbanization. Scholars found that the poor and low-income people continued to invade the middle-class community. They force hundreds of middle-class people to flee to the peripheral suburbs of the next circle. This phenomenon is called the trickle-down effect. Because of the poor quality of housing in the central city, a large number of poor people and immigrants gathered around, further damaging the community space environment in the inner city[7]. In addition, people aging leads to an imbalance in the urban population structure, which will also lead to the loss of the overall urban population[8].

## 2.3 Historical Background of Northeast of China

The northeast of China was the industrial core area and the vital industrial base in China. Rapid industrialization made the urbanization level of Northeast China lead the whole country for a time[9]. The “reform and opening-up” policy has focused on growth and expansion. However, urban shrinkage has occurred in some traditional industrial cities since the early arrival of the Lewis turning point in the 21st century.[10]

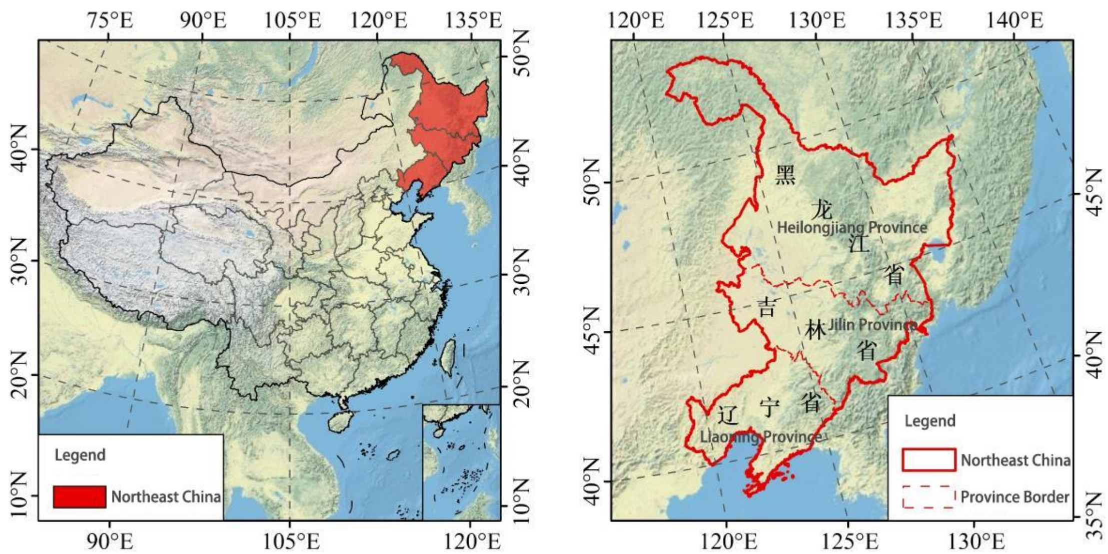



Figure 3 – Location of Northeast China

## 2.4 Transformation of planning paradigm

As the classic "urban growth machine" theory[11] demonstrated, the essence of local development is to grow and operate continuously as a machine. For a long time, growth-oriented planning has played a leading role in the decision-making process of local government[12]. Therefore, urban researchers are always reluctant to recognize or admit the shrinking because it seems to indicate that cities are decaying. Many local government decision-makers refer the urban shrinkage as a "shame" against their decision-making vision[13].

# 3 Methodology

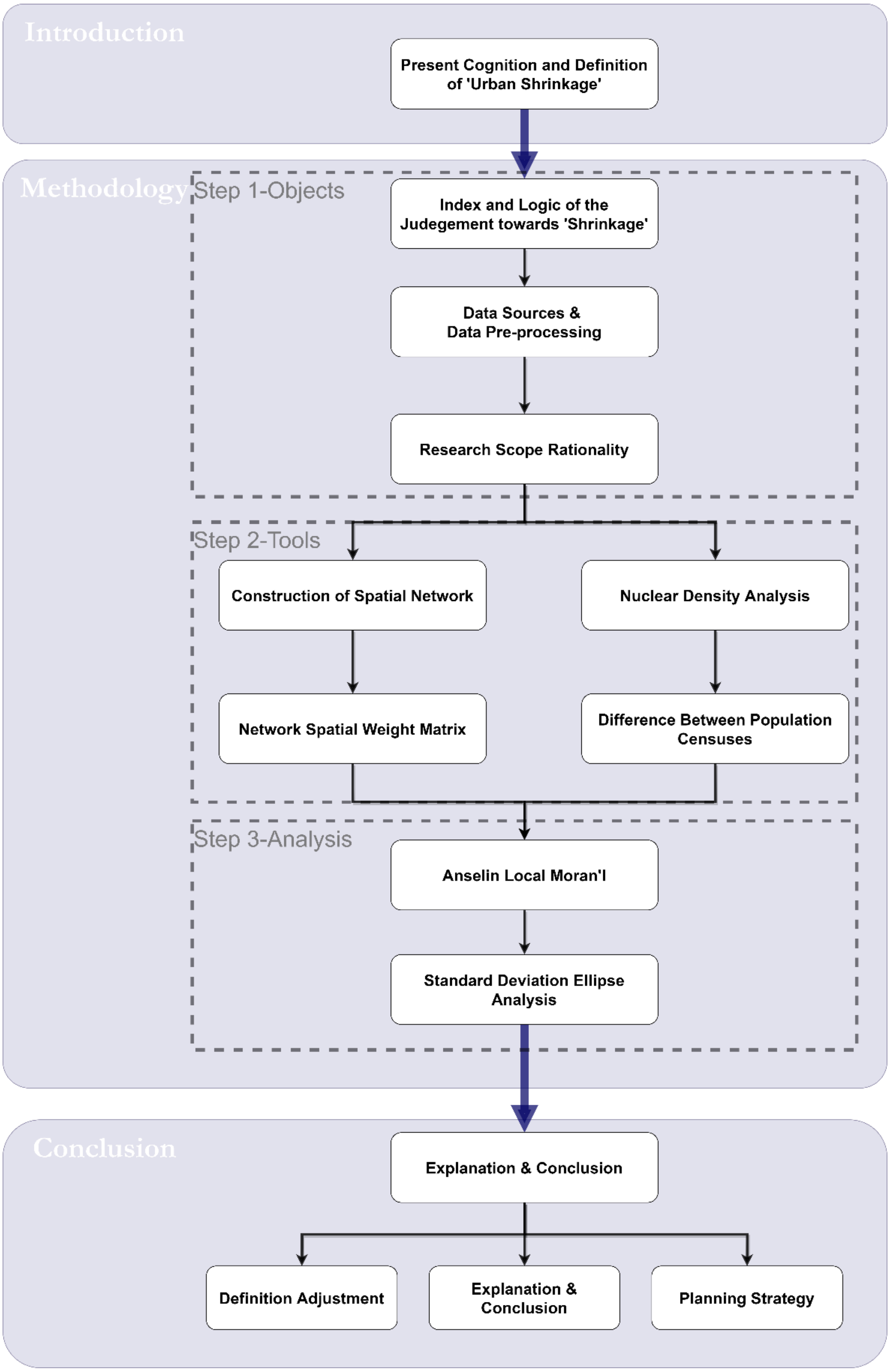



Figure 4 – Proposed Research Method

## 3.1 Relating Measurement towards ‘Shrinkage’

By summarizing and optimizing the existing definition of urban shrinkage, the narrow sense of ‘Urban Shrinkage’ is defined as a continuation of population loss in urban (town) areas and the general characteristics of permanent loss, which is the core of urban contraction. The generalized definition of urban shrinkage refers to the overall decline of population, economy, society, environment, culture, etc.

### 3.1.1 Population - Core Index

The aspects of the regression consist of society, economy, and other factors. They can be generalized as the consequences of population loss results. These factors can be concluded as the various secondary aspects reflecting the shrinkage. Therefore, the loss of "population" is an essential indicator of urban shrinkage. The economic, social, environmental, and cultural factors mentioned in a broad sense are all secondary influencing factors of "population". Consequently, the spatial distribution of the population is seen as the core index of the analyzing system in the process of urban shrinkage.

### 3.1.2 Transportation – Vital Spatial Carrier

All the spatial mobility of the population is based on transportation infrastructure. Therefore, it is necessary to focus on the population and the spatial carrier of the "flowing population" (transportation network). By organizing relevant traffic data, according to the statistics of relevant national departments, highway traffic accounts for 71.3% of the total passenger traffic, and railway accounts for about 22%. Besides, the railway network is highly consistent with the highway network. Therefore, the overall traffic network system can be equivalent to the road spatial network form.


Figure 5 – Typical Cases of Classification of highways in China

| *Categories* | *Design Hourly Traffic Volume* | *Details* |
|---|---|---|
| *Expressway* | ≥15000Passenger Cars | Controlled Gate |
| *$1^{st}$-class highway* | ≥15000Passenger Cars | Flexible Gate |

| | | |
|---|---|---|
| *2nd-class highway* | 5000-15000Passenger Cars | Dual-Lane |
| *3rd-class highway* | 2000-5000Passenger Cars | Non-Motor Vehicle Allowed |
| *4th-class highway* | ≤2000Passenger Cars | Single Lane Allowed |

Table 1 - Classification Standards of highways in China

China's highway network planning divides the highway network into five different classes: expressway, first-class highway, second-class highway, third-class highway, and fourth-class highway. The division standard is shown in Table 3-1. According to Figure 5 and Table 1, 3rd-class and 4th-class highways could be excluded because they mainly functioned as a substitute when the commute distance is below 100km. Moreover, their traffic volume account is lower than 20%.

## 3.2 Data Sources & Data Pre-processing

There are two different kinds of the population in statistics, the Permanent Population and the Registered Residence Population. The Registered Residence Population means the number of people who register their identification information in the relevant departments of the local government; The permanent population refers to the population living in the research area for more than a certain period.

Considering the definition and statistical habits, we choose the resident population as the statistical standard, which is also the statistical standard adopted by the Chinese government for population censuses.

Data preprocessing refers to the processing of data before the main analysis. For example, before the transformation or enhancement of most geophysical areal observation data, the irregular distribution survey network is first transformed into a regular network through interpolation to facilitate computer operation. More importantly, we need to select a platform for processing spatial data. This article will use ArcGIS as the basic platform for spatial analysis and data visualization.

## 3.3 Research Scope Rationality

Before the integration and analysis of relevant spatial information within the research scope, we need to confirm whether the research scope has spatial correlation under administrative divisions.

Because the spatial distribution of terrain, geomorphology, and other factors is inconsistent with the boundary of administrative divisions, it is necessary to detect the spatial autocorrelation within the selected research scope through Global Autocorrelation Analysis. If there are areas with low autocorrelation, the research scope needs to be adjusted or clipped accordingly.

Therefore, the Global Autocorrelation Analysis tool is used to detect the spatial data of the population with a certain sense of spatial correlation. Also, The incremental spatial autocorrelation tool is used to find out the variation of spatial statistics at different distances and the statistical distance when the spatial statistics are most significant. The correlation results provide reference for the parameter standards of subsequent analysis.

## 3.4 Construction of Spatial Network

The relevant vector data of administrative region boundaries and road network systems are downloaded through the National Geographic Information Resource Catalog Service System, and then these data will be imported into ArcGIS for preliminary data sorting.

Figure 6 - Schematic Map of Spatial Network Construction

According to the classification of highways, expressways, 1st-Class I highways, and 2nd-Class highways are reserved and classified into different layers. The network dataset will then be generated and constructed.

## 3.5 Network Spatial Weight Matrix

This study uses the spatial relationship modeling tool in ArcGIS to generate the spatial weight matrix based on the traffic network. Generally, we will take the Euclidean distance of the space point in the projection coordinate system as the weight measurement index. But there would be a defect that we ignore: the population flow in space is based on the road network. Moreover, The traffic road network is affected by factors such as geographical environment and administrative division. It is non-linear in space and cannot be equal to Euclidean distance. Therefore, constructing the network spatial weight matrix based on the accessibility of transportation could be a proper way to construct the model of spatial relationships.

## 3.6 Nuclear Density Analysis

The population density distribution in the northeast of China was analyzed in the year 2010 and 2020 respectively through the Nuclear Density Analysis tool(Figure 7).

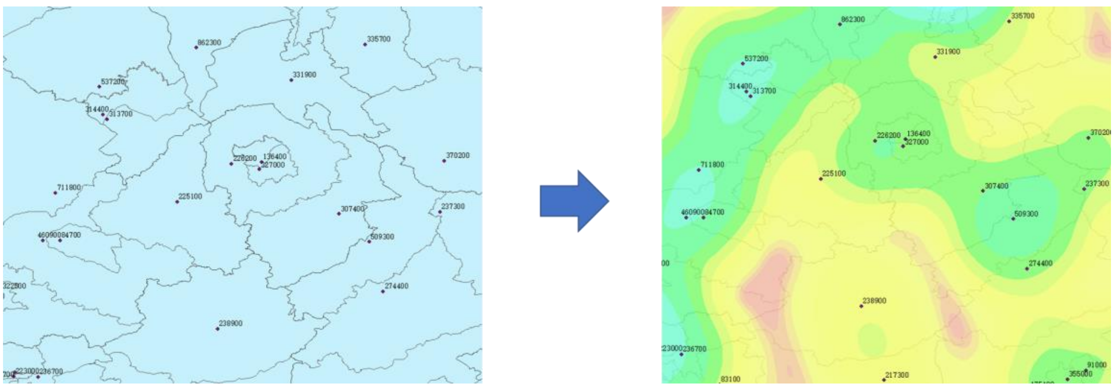


Figure 7 - Schematic Map of Nuclear Density Analysis

The selection of the 'search radius' parameter value in the kernel density tool needs to refer to the results of Incremental Spatial Autocorrelation Analysis mentioned in 3.3 Research Scope Rationality. The analysis would be more convincible through setting current situation as baseline.

## 3.7 Difference between Population Censuses

Overlay Analysis would be used to process the results of Nuclear Density Analysis. It summarizes the spatial distribution of population inflow and outflow by difference values(Figure 8).

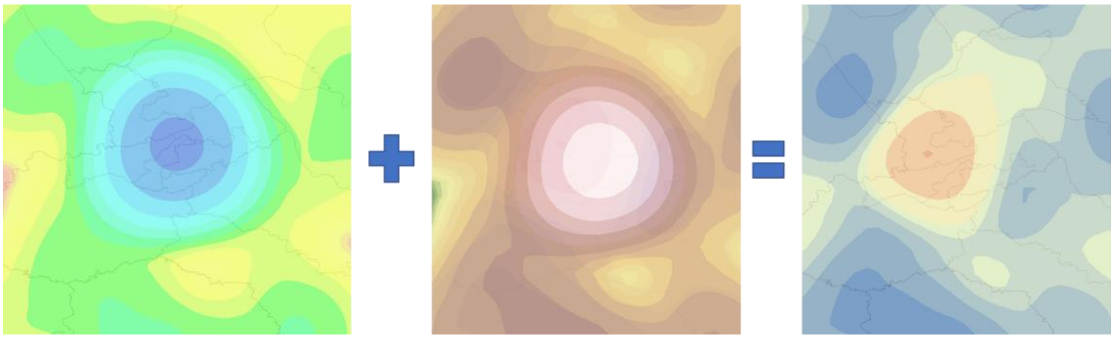


Figure 8 – Schematic Map of Population Raster Calculation

Compared with directly subtracting the population in different periods, using Raster Calculator tools to calculate the corresponding grid based on the spatial analysis could be a better way. Because the spatial distribution center of the population is considered rather than the total administrative population.

## 3.8 Analysis-Anselin Local Moran'I

Using the spatial weight matrix obtained mentioned in 3.5 Network Spatial Weight Matrix as the spatial weight reference coefficient variable, the spatial heterogeneity based on population distribution data is grouped and identified through local spatial autocorrelation analysis. The next step is to judge high-high cluster areas and spatial outlier areas. Then, the population spatial distribution results would be superimposed and compared.

## 3.9 Standard Deviation Ellipse Analysis

The standard deviation ellipse is a spatial statistical technique to measure the distribution of geographical elements θ. The standard deviation of parameters such as the X-axis and Y-axis is used to analyze the characteristics of the spatiotemporal distribution. Taking the result of cluster category judgment as a parameter, followed steps are to substitute it into the population distribution data, and to use the standard deviation ellipse tool to analyze the main concentration areas and main flow directions of population flow from a wide area perspective.

## 3.10 Summary

The analysis charts are generated by various analysis tools which summarize various characteristics of spatial data and find out the rules and special points from the perspective of data analysis from the characteristics of space.

Compared with the existing inherent cognition, conclusions would be summarized that why it is the same or contrary to the common-sense cognition, and make corresponding decision adjustments to guide the planning better.

# 4 Case Study

The case study area selected in this paper is the northeast region of China (Northeast China) which includes Heilongjiang Province, Jilin Province, and Liaoning Province(Figure 9). Northeast China has been the industrial center of China in the last century. Its population and economy developed rapidly due to its high-quality land resources, industry, and agriculture.

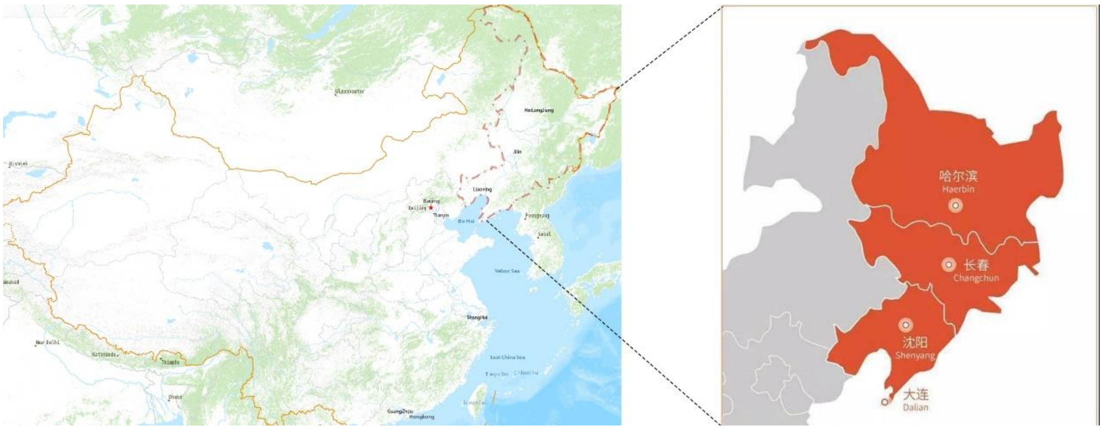



Figure 9 - Location of the Case Research Scope

As the decline of the competitiveness of the original urban role, the northeast region of China had to resolve significant development challenges. After the ‘Reform and Opening-up policy in 1978, China's southeast coastal areas have become new poles of the economic engine, and the sales of industrial products in the northeast have begun to face a huge crisis. Meanwhile, due to the adjustment of national policies, Northeast China gradually declined after entering the 21st century. The population outflows and the industry gradually becomes the core market competitiveness of the urban area. In short, the decline of Northeast China is affected by various factors such as resource depletion, policy impact, industrial product adjustment, and the imbalance of the tertiary industry structure. However, all these factors eventually led to a simple phenomenon – losing its dominant role in the national economic system. A large number of people flowed out to other regions due to lacking employment opportunities.

## 4.1 Data Resources & Processing

After delimiting the scope, the first thing to determine is whether it is reasonable to delineate the research scope according to the administrative division. Many factors affect population distribution in space such as natural terrain, climate, traffic location, etc. The administrative region is the least influential factor. Therefore, it is necessary to use global autocorrelation analysis to judge whether there are clustering features in the research scope.

Population spatial data was imported into ArcGIS, and global spatial autocorrelation analysis Moran'I was applied to verify the correlation of population data in the research region. The verification results are shown below (Fig. 10).

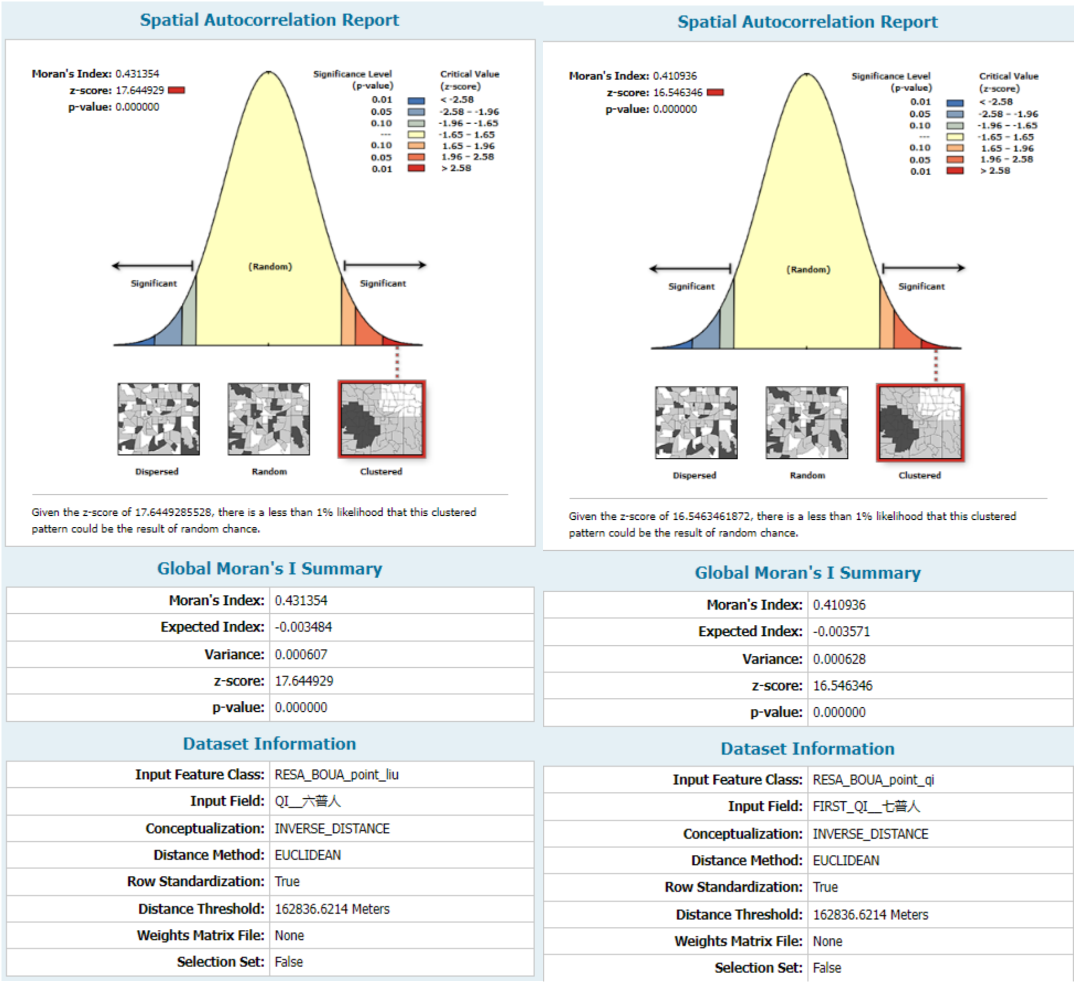


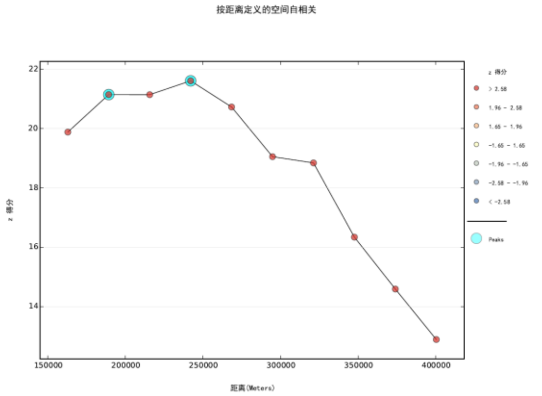

Figure 10 - Spatial autocorrelation report of population data in 2010 & 2020

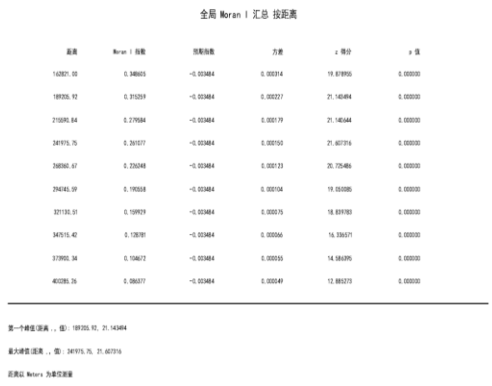
| *Year* | *Global Moran' I* | *Z-score* | *P-value* | *Expected Index* | *Variance* |
|---|---|---|---|---|---|
| *2010* | 0.431354 | 17.6450 | 0.0000 | -0.0034 | 0.0006 |
| *2020* | 0.410936 | 16.5463 | 0.0000 | -0.0036 | 0.0006 |

Table 2 - Global Autocorrelation Analysis Results

It can be seen from the above table that the global autocorrelation analysis results show that the spatial distribution data of the population in the selected region has spatial autocorrelation characteristics, and the data is clustered. The population data of 288 districts (counties) in the northeast region is spatially related and clustered.Therefore, we can assume that there could be some features to seek out in the clustered scope.

Besides, we still need to use the 'Incremental Spatial Autocorrelation' in ArcGIS to find the standard distance for measuring the spatial distribution of existing urban agglomerations. The results (Figure 11) show that, with the increase of distance parameters, the spatial autocorrelation Z value reaches the maximum at a distance of about 240 km. The results of spatial autocorrelation have the most significant spatial clustering results when the standard is nearly about 240 km.



全局 Moran I 汇总 按距离

| 距离 | Moran I 指数 | 预期指数 | 方差 | z 得分 | p 值 |
|---|---|---|---|---|---|
| 162821.00 | 0.348605 | -0.003484 | 0.000314 | 19.878955 | 0.000000 |
| 189205.92 | 0.315259 | -0.003484 | 0.000227 | 21.143494 | 0.000000 |
| 215590.84 | 0.279584 | -0.003484 | 0.000179 | 21.140644 | 0.000000 |
| 241975.75 | 0.261077 | -0.003484 | 0.000150 | 21.607316 | 0.000000 |
| 268360.67 | 0.226248 | -0.003484 | 0.000123 | 20.725486 | 0.000000 |
| 294745.59 | 0.190558 | -0.003484 | 0.000104 | 19.050085 | 0.000000 |
| 321130.51 | 0.159929 | -0.003484 | 0.000075 | 18.839783 | 0.000000 |
| 347515.42 | 0.128781 | -0.003484 | 0.000066 | 16.336571 | 0.000000 |
| 373900.34 | 0.104672 | -0.003484 | 0.000055 | 14.586395 | 0.000000 |
| 400285.26 | 0.086377 | -0.003484 | 0.000049 | 12.885273 | 0.000000 |

第一个峰值(距离 ., 值)：189205.92, 21.143494

最大峰值(距离 ., 值)：241975.75, 21.607316

距离以 Meters 为单位测量

Figure 11 - Results of Incremental Spatial Autocorrelation_150-400km


Figure 12 - Spatial Distances between cities Compared with Analysis Results

It is a reasonable research perspective to delimit the scope of urban agglomeration with a radius of 240km and the core city as the center. Therefore, the administrative regions of the three provinces can be selected as the research area. Also, at the same time, the spatial distance of the city can verify the results of the incremental autocorrelation analysis. The coverage results of the city are 240km, which shows that the maximum value of the incremental autocorrelation analysis result is valid and can be used as a reference for subsequent analysis.

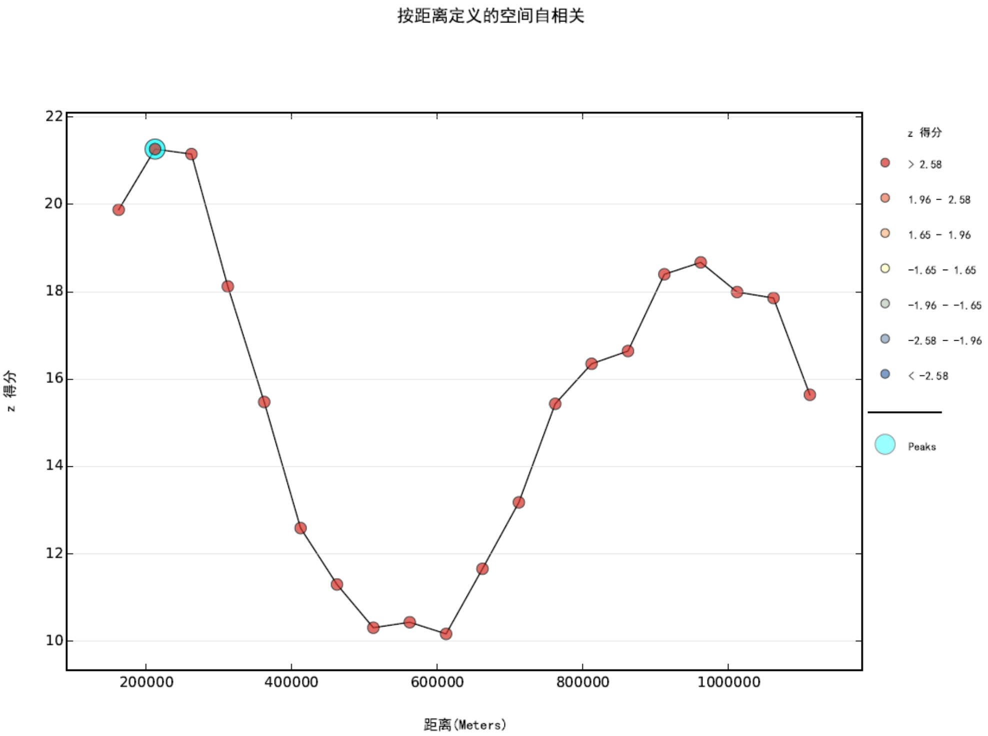



Figure 13 - Results of Incremental Spatial Autocorrelation_160-1100km

In addition, we can also find in Figure 13, when the reference distance is about 600km, the clustering effect of global autocorrelation is the weakest, which can be explained in the following two ways.

Firstly, due to the space limitations of the selected research scope, the maximum linear distance in the east-west direction is about 700km. Considering that the accessibility distance behind the traffic network is about 800-900km. The incremental autocorrelation analysis results will reach the lowest value at about 600km.

Secondly, as the north-south straight distance has exceeded 1200km, we still believe that the limit distance of spatial interaction between cities is about 600km. It can also be explained that 600km means about 6-hour time-cost, which corresponds with the traditional commuting habits in China.

Based on the incremental spatial autocorrelation data, the autocorrelation Z score is the lowest when the distance is about 600 km. At this time, although the autocorrelation coefficient grows again with the increase of distance, it can be attributed to other non-spatial geo factors instead of Tobler's geography principle. Everything is related to everything else, but near things are more related to each other. According to the results of incremental autocorrelation analysis, the assumption could be made that the limit value of the influence range of any city on the population attraction or repulsion of its surrounding cities is about 600km.

## 4.2 Population Flow

The spatial flow of the population is based on the traffic network system. Relevant research has concluded that the railway network layout and highway network layout in Northeast China are highly spatial related. In addition, the transport volume of railway transport is relatively small compared with road transport. According to relevant data[14], road transport accounts for more than 70% of the total transport volume in China by the end of 2019; Therefore, the highway network is simply taken as the analysis object here.

## 4.3 Spatial Network Analysis


Figure 14 – Visualization of Network Dataset in ArcMap

The spatial network weight tool in GIS is used to generate the spatial weight matrix based on the network data set(Figure 14). The result will be a table with 33770 rows as follows (Figure 15). In the 'Spatial Weight Matrix' tool, the impedance parameter has been set as 600km according to the previous incremental spatial autocorrelation data to make sure that every pair of connected cities is calculated in a proper distance range.

| WEIGHT | LOCAT * | Y | X | LOCAT |
|---|---|---|---|---|
| 0.157758 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市平房区 |
| 0.15568 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市道外区 |
| 0.154129 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市香坊区 |
| 0.153634 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市南岗区 |
| 0.14695 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市道里区 |
| 0.133934 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市松北区 |
| 0.120032 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市呼兰区 |
| 0.115275 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市双城区 |
| 0.106275 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市宾县 |
| 0.09945 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市尚志市 |
| 0.095375 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市巴彦县 |
| 0.095255 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 绥化市兰西县 |
| 0.091739 | 哈 Start point | 45.54622 | 126.972889 | 绥化市肇东市 Destination |
| 0.088907 | 哈 | 45.54622 | 126.972889 | 松原市扶余市 |
| 0.087798 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市五常市 |
| 0.084371 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 长春市榆树市 |
| 0.084052 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市延寿县 |
| 0.07909 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 绥化市北林区 |
| 0.078708 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 绥化市青冈县 |
| 0.078583 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市木兰县 |
| 0.074205 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 大庆市肇州县 |
| 0.0735 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 长春市德惠市 |
| 0.073107 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 绥化市安达市 |
| 0.071628 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 绥化市望奎县 |
| 0.071051 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 大庆市龙凤区 |
| 0.070777 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 吉林市舒兰市 |
| 0.070776 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市方正县 |
| 0.070504 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 绥化市庆安县 |
| 0.06885 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 哈尔滨市通河县 |
| 0.068732 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 大庆市肇源县 |
| 0.068425 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 大庆市萨尔图区 |
| 0.067673 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 绥化市明水县 |
| 0.06657 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 大庆市让胡路区 |
| 0.066298 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 松原市前郭尔罗斯蒙古族自治县 |
| 0.06624 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 长春市农安县 |
| 0.066162 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 松原市宁江区 |
| 0.065867 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 绥化市绥棱县 |
| 0.06495 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 长春市九台区 |
| 0.064292 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 大庆市大同区 |
| 0.063676 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 伊春市铁力市 |
| 0.063155 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 绥化市海伦市 |
| 0.062616 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 长春市宽城区 |
| 0.06201 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 牡丹江市海林市 |
| 0.061723 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 长春市二道区 |
| 0.061663 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 吉林市船营区 |
| 0.061654 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 吉林市昌邑区 |
| 0.061149 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 吉林市丰满区 |
| 0.061094 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 吉林市龙潭区 |
| 0.061036 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 长春市绿园区 |
| 0.06092 | 哈尔滨市阿城区 | 45.54622 | 126.972889 | 大庆市杜尔伯特蒙古族自治县 |

Figure 15 - Spatial Weight Between Cities Based on Network Dataset

The spatial weight matrix is visualized in Figure. 16; It represents the spatial distance weight between two residential (geometric abstract) points within a certain distance. It can be generally understood that the traffic between two spatial locations can reach an important degree.

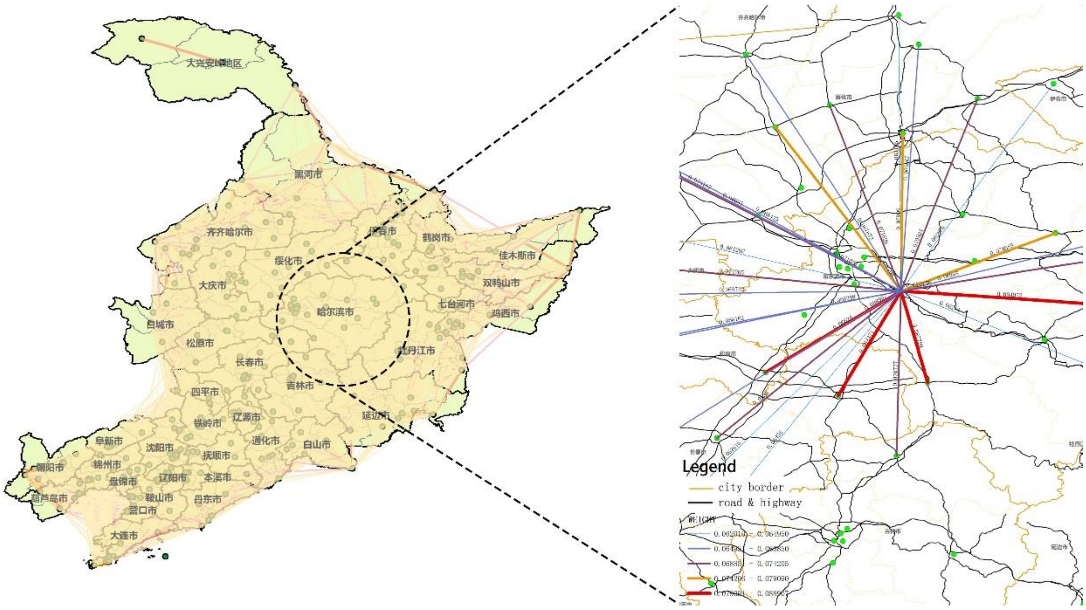



Figure 16 - Spatial Weight Matrix Visualization

The visualization of the overall spatial weight matrix is shown in the figure above. Since the impedance parameter is set to 600km, there are about 150-200 weight-related points connected to each point, and the overall number of line elements is 33770. Therefore, the specific diagram is made after amplification. The difference must be clarified that the weight matrix between the two points is calculated based on the road network accessibility instead of the Euclidean distance represented in the schematic diagram.

## 4.4 Population Spatial Distribution

### 4.4.1 Population Distribution Features

Firstly, the polygon shapefile composed of all residential areas in each administrative division is converted into a point shapefile, and different population quantity attribute fields are given to each point element. The population density distribution maps in 2010 and 2020 are obtained through nuclear density analysis in Figure 17.

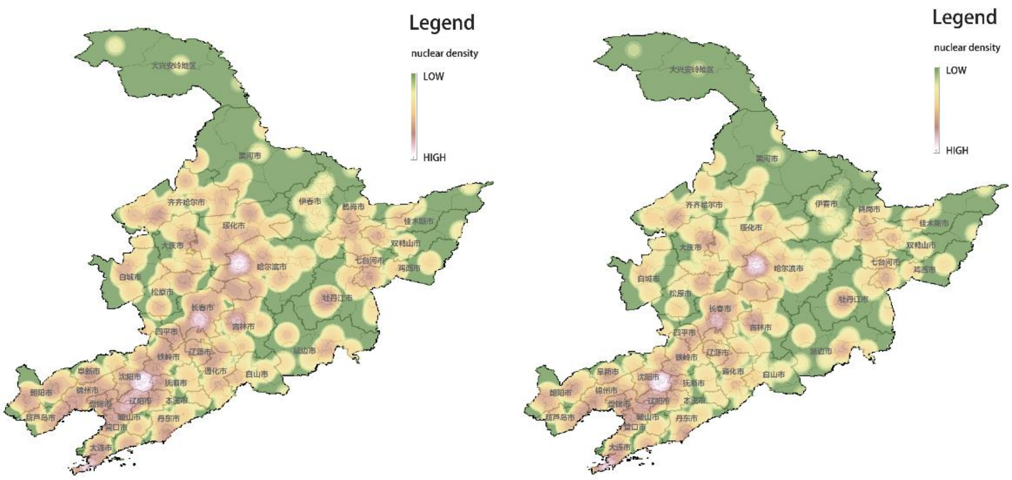



Figure 17 - Nuclear Density Analysis of Population Distribution (left:2010, right:2020)

From the figure 17, we can see that there are three distinct population density centers in northeast China, namely, the provincial capitals (central cities) of the three provinces. However, based on the comparison between 2010 and 2020, we can see the population agglomeration effect of the two provincial capitals in the north is slightly weakened, while a larger range of high-density population agglomeration is formed in the south.

### 4.4.2 Population Density Difference

The population distribution density map of Northeast China from 2010 to 2020 is calculated by the grid, and the population change in 2020 compared with 2010 is obtained. The red area represents the population density increases and the blue area represents the population density decreases(Figure 18).

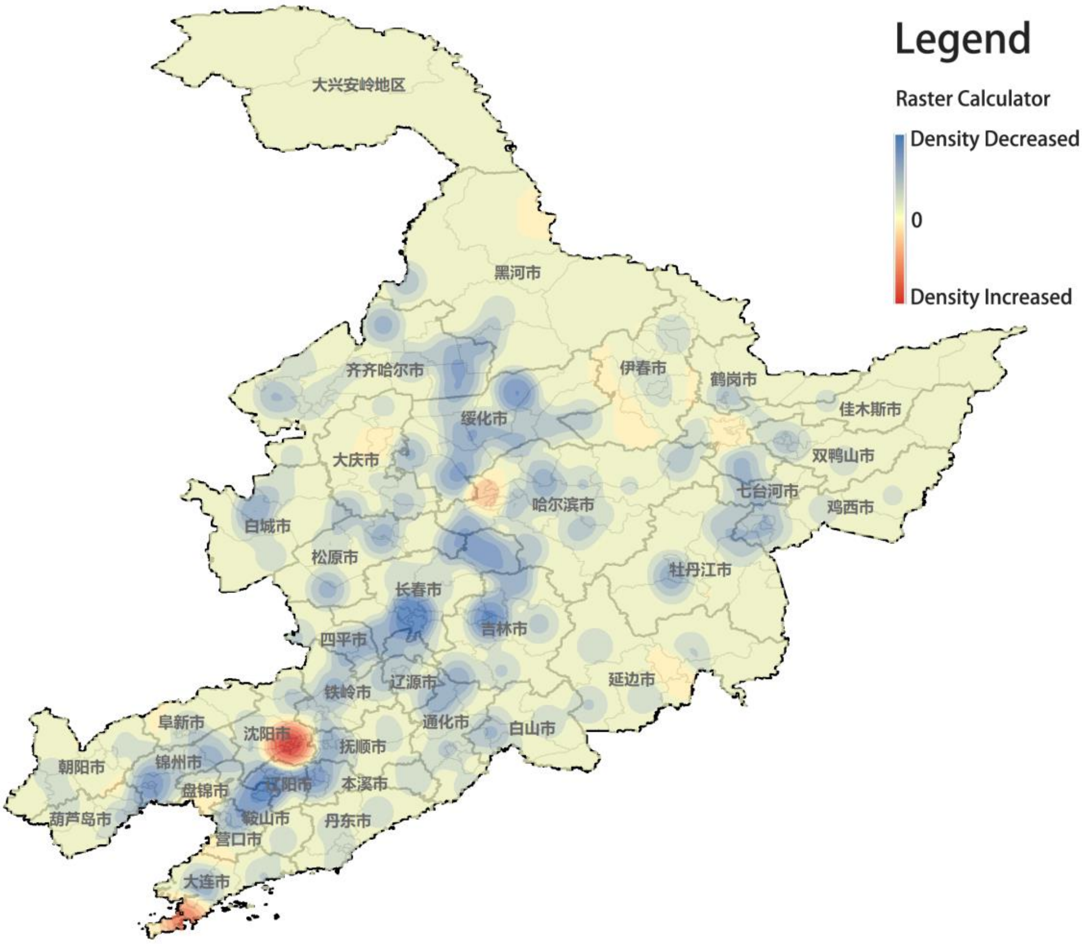



Figure 18 - Raster Calculator Results of Difference Between Density of 2010 & 2020

In the past ten years, only two cities in the southern part were the core of population inflow. The central region is basically in an outflow state.

At the same time, there is a small population reduction in the northern region. Considering the overall aging background of China and the realistic factors of reducing the birth rate and increasing the mortality rate, the reduction of population density in the northern and eastern regions is reasonable and acceptable. It is not similar to the sharp decline of the population in Detroit or Ruhr Industrial Zone.

## 4.5 Anselin Local Moran'I & Standard Deviation Ellipse Analysis

Based on the spatial weight matrix obtained in 4.3, local autocorrelation clustering analysis is carried out in the research scope.

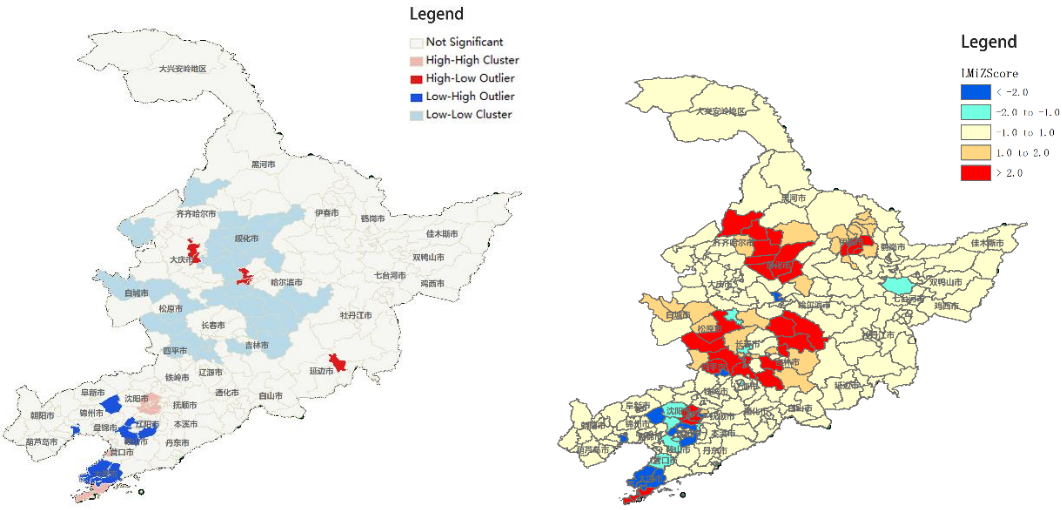



Figure 19 – Analysis Result of Anselin Local Moran'I & High-Low Clustering

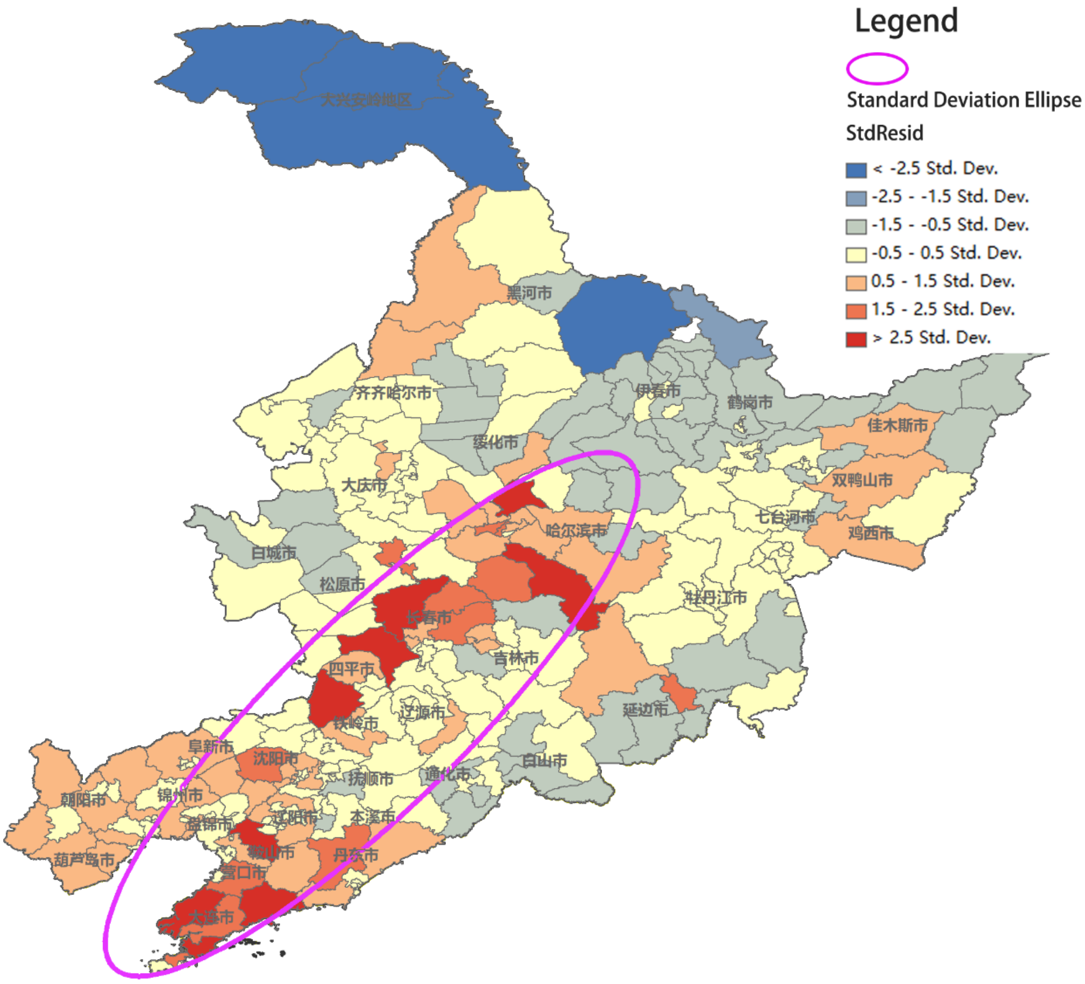



Figure 20 - Standard Deviation Ellipse Analysis Results based on Geographically Weighted Regression

By comparing the standard deviation ellipse with the density difference, the conclusion should be drawn from three perspectives:1) the relation between population mobility and network; 2) the center of population flowing; 3) external relevance.

### 4.5.1 Correlation between population mobility and network

The northwest corner is sparsely populated except the blue area does not involve the road network. The standard deviation of the regression coefficient of the yellow area is within a reasonable range, which proves that the population flow in its space conforms to the spatial flow law based on the road network model. Therefore, the spatial accessibility based on the road network still positively correlated with the basis of population flow. We conclude that the increase and decrease of population flow are within the positive correlation range of the road network

### 4.5.2 center of population flowing

However, high flow of population flows (inflow & outflow) occur within the coverage of the standard deviation ellipse in a high concentration type of local autocorrelation. In the range of local autocorrelation, the population distribution density shows a trend of concentration from the marginal area to the regional center. It is not a "global contraction" in common sense. Its essence is the reorganization of the population at the level of wide area space. It shows that "central cities" with stronger economic strength, and more policies siphon the labor force and population of surrounding cities like "blood-sucking".

#### 4.5.3 Low-level external relevance

At the same time, the standard deviation ellipse is still concentrated in the central area of the urban agglomeration in the south, which indicates that the direction and scope of spatial data aggregation indicated by the standard deviation ellipse are still within the overall research scope of the northeast region. It also indicates that the main type of population flow in the overall northeast region is the orderly flow and regulation of population within the urban agglomeration rather than the traditional negative feedback "loss" and "urban decay".

### 4.6 Summary

Different from the traditional analysis of directly comparing "population reduction", I found that after taking the variable of "spatial connectivity and accessibility of urban agglomeration" into consideration, urban contraction can be identified and summarized as "secondary urbanization. To some extent, population flows from low-level cities to high-level cities" within urban agglomeration in a wide area, just as the first urbanization "population flows from rural areas to cities". The “shrinkage” shouldn’t be regarded as a problem to handle, but could motivate the second round of “urban agglomerationalization”. The new change means a new chance of the overall optimization of urban spatial structure.

## 5 Limitation & Future work

### 5.1 Data Accuracy

The major limitation of the present study is the inevitable error of the acquired relevant residential data because the level of population data can only be subdivided into the district and county levels instead of the street(block) level. It is difficult to obtain more precise relevant data, so the spatial analysis may have some inaccuracy.

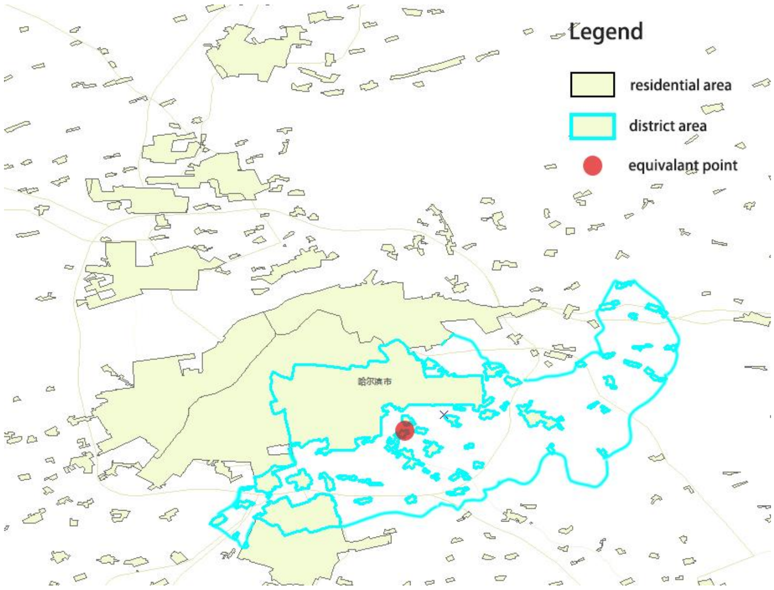


Figure 21 - Low Accuracy of the Population Spatial Distribution Quantity

For example, we can accurately express the residential area features in each district and county (Figure 21). It is impossible to assign an independent population to each polygon because we do not know the explicit number of every residential area. All the population numbers within the administrative scope can only be attributed to an equivalent point which is the geometric center of all the residential areas.

## 5.2 Generality

Another concern about the findings is the research method of this study has certain limitations in terms of universal promotion due to the selection of cases. For example, in other countries, the transportation modes may be not similar to those in China. The high-density airport distribution of the United States will partly weaken the impact of the road network on the spatial population flow.

## 5.3 Future work

Future research should be undertaken in exploring the validity of the tools used in this research. The model has the potential to be optimized to measure the correlation between the spatial network and population flow. And we might identify the possibility of future shrinkage clearly and precisely through adding Spatiotemporal Weighted Regression Model into current research.

# 6 Conclusion

## 6.1 Re-thinking of Shrinkage

In previous studies, shrinkage was usually referred to as a bad state of the city in need of adjustment and renewal. It stems from nearly 100 years of urbanization, where the line between "development" and "urban expansion" is so tight that there is an idea in our subconscious that "shrinkage" means "decline" for cities. Though the urban population decreases from a certain perspective, complex urban cluster composed of multiple cities maintains the population balance to the extent of problem.

Therefore, shrinkage, a word with negative effects, cannot describe the changes in spatial population mobility in this process. It is true that after the impact on the old industrial structure of the city, the city will certainly be in its throes. However, from a broader perspective, urban contraction is a spatial reorganization of the population in a large space under the influence of the market, capital, and other factors.

## 6.2 Hypothesis on the mechanism

We can hypothesize that we should stop setting the 'city level' as the unique core object in the process of planning (Figure 22). In the past, we used to define urban planning programs as the core content in the planning system, but it's time now to broader our horizons. Urban agglomerations should be considered as an important domain within which many research outcomes will vary greatly.

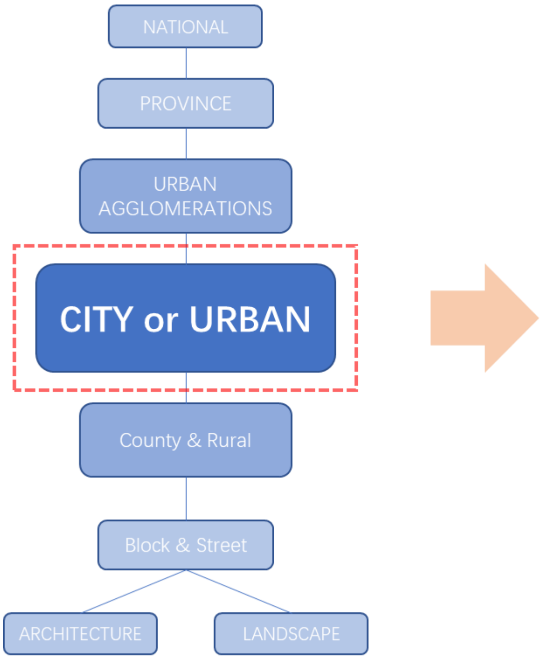



Figure 22 - Shifting of the Key Objects in the Regional Planning Mechanism

With the increase in communication frequency between cities and the further improvement of traffic capacity, a broader urban agglomeration structure has been formed between cities (Figure 22).

This urban agglomeration is not simply a combination of built-up areas because there are large areas of villages, farmland, or natural environment between urban built-up areas and residential areas. The flow of factors such as population, capital, and industries between cities forces us to stop studying a city from a narrow "urban perspective", and to place it in the urban cluster structure within its wide range. Therefore, we could have a clearer understanding of the nature of its urban contraction. The research on other urban elements can also be more effective and innovative.

## 6.3 Planning Strategy

The main contribution of the article is to provide a new perspective for the follow-up study about the dynamic evolution of cities. The experience gained from this study is to consider the role and location of cities in urban agglomerations rather than being constrained by municipal governments and urban administrative boundaries. We proposed a hypothesis that city (urban) planning, currently dominated by the municipal government, would be replaced by broader spatial agglomeration planning as the basic research object in the future. Compared with the traditional urban master plan, the urban agglomeration plan has greater advantages:

1) To clarify cities' functional orientation.
2) To allocate spatial resources.
3) To guide the orderly flow of the population.
4) To form a stable and sustainable agglomeration system.

We suggest that urban planners should evolve with 'spatial urban agglomeration planners' to avoid the inefficient use of spatial population resources and promote regional development.

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