Study of Influencing Factors of Shrinking Cities Based On Factor Analysis – The Example of Halle, Germany

Fang Yao, Minglei Chen

Abstract—City shrinkage is one of the thorny problems that many European cities have to face with nowadays. It is mainly expressed as the decrease of population in these cities. Eastern Germany is one of the pioneers of European shrinking cities with long shrinking history. The paper selects one representative shrinking city Halle (Saale) in eastern Germany as research objective, collecting and investigating nearly 20 years (1993-2010) municipal data after the reunification of Germany. These data based on five dimensions, which are demographic, economic, social, spatial and environmental and total 16 eligible variables. Factor Analysis is used to deal with these variables in order to assess the most important factors affecting shrinking Halle. The results show that there are three main factors determine the shrinkage of Halle, respectively named "demographical and economical factor", "social stability factor", and "city vitality factor". The three factors act at different time period of Halle's shrinkage: from 1993 to 1997 the demographical and economical factor played an important role; from 1997 to 2004 the social stability factor is significant to city shrinkage; since 2005 city vitality factor determines the shrinkage of Halle. In recent years, the shrinkage in Halle mitigates that shows the sign of growing population. Thus the city Halle should focus on attaching more importance on the city vitality factor to prevent the city from shrinkage. Meanwhile, the city should possess a positive perspective to shift the growth-oriented development to tap the potential of shrinking cities. This method is expected to apply to further research and other shrinking cities.

Keywords—Demography, Factor analysis, Halle, Shrinking cities.

I. INTRODUCTION

EVEN though the world's population continues to grow, many European countries are undergoing considerable demographic changes and experiencing the challenge of shrinking cities [1]. Nowadays, urban shrinkage is one of the top political agendas in Europe. Many study findings have revealed that urban shrinkage has become a reality for many places in Europe [2], [12]. In fact, after the collapse of the socialism many cities in Central and Eastern Europe began to depopulate. Up until now, about 40 percent of all European cities that have more than 200,000 inhabitants have lost population in a short-, medium-, or long-term period for different reasons [3]. It seems that population decrease in many cities are inevitable in the coming decades [4]. However, for the past two hundred years, city planning had been almost focused on the process of growth and there was barely theory of

Fang Yao was with the Bauhaus-Universität Weimar, 99423 Germany. She is now with the College of Architecture and Urban Planning, Tongji University, Shanghai, 200092 China (cellphone: +86 18612045156; e-mail: fangyao0818@gmail.com).

Minglei Chen was with the Bauhaus-Universität Weimar, 99423 Germany. He is now with the College of Architecture and Urban Planning, Tongji University, Shanghai, 200092 China (e-mail: thundercml@gmail.com).

shrinkage. Shrinkage poses a real threat to cities, both to their inhabitants and decision makers, which suggested that urban shrinkage demands new approaches to urban planning, design and management [2], [13]. To manage and restructure shrinking urban regions in Europe is one of the most challenging tasks for European cities in the forthcoming years.

Urban planning is challenged by shrinkage because the planning process has to assess its social, environmental and spatial effects both qualitatively and quantitatively. It is clear that shrinkage affects more than one dimension of urban development and spatial planning. Factor analysis can act as an effective auxiliary method applying to the study of shrinking cities. The process of shrinkage not only involves in demographic changes, but also relates to obvious or non-obvious social, economic, environmental as well as land-use changes. These components complicated interweave together with the shrinking cities. Therefore with the aids of quantitative analyses, we can help reduce the confusion caused by these problems and will be conducive to make comparison. This paper uses Factor Analysis to explore the impact factors behind shrinkage, thus to obtain valid conclusions of the development and implementation for future urban and regional policies.

II. SHRINKING CITIES IN GERMAN CONTEXT

A. What is Shrinking City

Shrinking city is never a new phenomenon to discuss but always the problem to concern. Typically, shrinking cities are those cities that have experienced considerable population loss over a prolonged period. Urban shrinkage is neither a marginal pattern of urban development nor a short-term divergence from the 'usual' growth path [1], [5], [14]. However, the reduction of local population is only the tip of the iceberg, which results from underlying complex sets of causes propelling specific problems for urban development [5], such as declining economy, rising unemployment, outward migration, surplus buildings and land [11]. In the post industrialization period, many European and North American cities shrank mainly because of the process of de-industrialization which caused the loss of employment and out-migrate of population. Plus, the process of suburbanization, the continually decreasing of fertility rates and extending of life expectance also contribute to shrinking cities [5], [6].

B. Shrinkage in Germany

Since the 1960s and 1970s, post-industrial transformations have occurred in West Germany that led to the shrinkage of urban cores [7]. By 1988, West German shrinking cities had

become distinct from growing ones. But since the reunification of Germany, population decline has become dramatically in former GDR (German Democratic Republic), which has lost between 10 to 20 percent of its residents in a period of 10 years [8]. Although there were enormous investments of the German federal government, the integration of East Germany into the Federal Republic of Germany has experienced much more problems than expected in the early post-reunification years [9]. Since then eastern Germany became the pioneers in terms of shrinkage-experience, there were a huge number of migrants moving from east part to west part and had made many eastern cities in shrinking process. It was stated that over one million flats in eastern Germany were vacant and it was expected that this number would be growing [10]. Today, urban shrinkage has been acknowledged as a process that is going to be occurring more frequently throughout Germany [4]. Depopulation not only occurs in eastern cities, but also in few western ones. In general, the shrinking area suffered from many problems that are difficult to solve, including high unemployment rate, losing population, high vacancies and suburbanization.

C. Research Objective: Halle (Salle)

Halle an der Saale, once famous for its salt, was a center of the GDR's chemicals industry and one of the important regional cities (Fig. 1). It was considerably enlarged by the construction of Halle-Neustadt (Halle New Town), which began in the mid-sixties. By 1990, about 94,000 people lived in the new district's pre-fabricated blocks of flats, most of them are the families of workers in the area's large chemical combines. The total population of the city Halle and Halle-Neustadt increased to 309,406 inhabitants in 1990.

Fig. 1 Location of city Halle an der Saale in Germany

During the period of industrialization, the definition of urban development and the assessment of its economy are primarily determined by presence of industrial enterprises in the city, which provided residents with jobs and attracted immigrants, resulting in increased population and demand for housing [15]. Thus, Halle-Neustadt appeared. As a result of further

globalization and technological advances, manufacturing enterprises did not have a great demand of employment and most factories have been replaced by enterprises of small business and service sector. After 1989, Halle tried to compensate for the collapse of its industrial base (mostly vehicle manufacture and mechanical engineering) by promoting administrative, scientific and cultural facilities.

Actually, during this period, among the most shrunk area in Central and Eastern European countries, 53 out of a total of 67 cities shrank. Among the ten cities with the highest relative loss of population- more than 1.75 percent annually, four were in Germany, which were all eastern Germany cities: *Halle an der Saale*, Frankfurt an der Oder, Schwerin and Magdeburg [4].

Nevertheless, the city Halle is suffering from a vacancy rate of 20 percent of its buildings. Hence, the demolition of housing is to take place from the outside in and mainly in the large housing estates in Halle. The government attempted to use demolition of housing in order to realize urban redevelopment.

The reason to choose Halle as the research objective is that Halle is one of the most representative shrinking cities in eastern Germany, where the shrinkage is the most serious. Since shrinking cities are mostly happened in small-to-middle size of cities, Halle is typical.

III. METHODOLOGY: FACTOR ANALYSIS

In order to analyze the main reasons that impact the shrinkage of Halle, models can be used as innovative tools to quantify the influence, thus to help us better understand what beneath the shrinkage. Frequently used approaches in urban planning modelling are statistical techniques such as Factor Analysis (FA), Principal Component Analysis (PCA) and Cluster Analysis (CA). Among them, Factor Analysis could ensure the minimal loss of information and maximally keep the authenticity of original data. These are necessary for comprehensively and subjectively analyzing what influence and contribute most to Halle's shrinkage, then further summarize the main reasons.

Factor analysis is a multivariate statistical analysis method that makes a number of original variables condensing into a few factor variables, and makes these factor variables strongly explanative.

A. Predictor Indicators for Shrinkage

Previous studies of literature have found that the causes and the performances of shrinking cities are complicated, therefore we tried to measure Halle's shrinkage from multiple and comprehensive perspectives. After considering the literatures and the data sources, five dimensions of variables are concluded to indicate the process of shrinkage, including demographic, economic, social, spatial and environmental dimensions.

1. Demographic Dimension

Urban shrinkage is driven by demographic changes. The most related variables include birth and death rate, aging population (over 65 years old), foreign and German population, short-term (less than 5 years) and long-term (more than 15

years) residences, immigrants and emigrants.

The birth and death number will affect natural population growth. Aging group of people is selected as a representative from the total age structure. The other three couples of population variables reflect the fluctuation of demography. Together all the different variables from the aspects of population structure and growth law reflect the demographic characteristics of Halle.

TABLE I
DEMOGRAPHIC VARIABLES AND MODEL RULES

Variable Series I	Statistic rule and proposal
Birth rate	annual ratio or absolute value
Death rate	annual ratio or absolute value
Aging population	population over 65 years old
Foreign population	absolute value annual
German population	absolute value annual
Short-term residences	population living less than 5 years
Long-term residences	population living more than 15 years
Immigrants	absolute value annual
Emigrants	absolute value annual

2. Economic Dimension

The economy best shows the development level of a city and has direct impacts on shrinking. It expressed as the total amount of economy, economic development of each sector, government's revenue and expenditure as well as living standard of local residents. The variables relate to all aspects of economic situation of the city, from macro to micro and from the government to the people.

Specific variables include Gross Domestic Product, number of employees of primary industry, secondary industry and tertiary industry, revenues, taxes and expenditures in Halle's municipal budget as well as disposable income of private household.

TABLE II
ECONOMIC VARIABLES AND MODEL RULES

Variable Series II	Statistic rule and proposal
Gross Domestic Product	in total or per inhabitant (Halle)
Disposable income of private household	according to household not individual
Employee in sector 1	include agricultural, forestry and fishing
Employee in sector 2	include manufacturing industry
Employee in sector 3	include Trade, transport & other service areas
Expenditures	government's outcome
Taxes	government's important income

3. Social Dimension

Social factors are also important reasons for population fluctuation. They mainly embody as whether the stability of society will attract or prevent exodus of population, and whether the changes in social components and family structure will in favour of population growth.

Social stability reflects by variables of crime rate and unemployed population. Mean size of household shows the family structure and the number of students partly shows the social component which probably related to large amount of population changes.

TABLE III
SOCIAL VARIABLES AND MODEL RULES

Variable Series III	Statistic rule and proposal
Crime representation	crime rate or the frequency number
Unemployment	unemployment rate or absolute value
Mean size of household	average people per household
Number of college students	students numbers in higher education

4. Spatial Dimension

The changes in urban space can also indirectly reflect the shrinkage of a city and show the effect of urban planning managing urban shrinkage. The spatial indicators mainly include two variables, one is the population density in built-up areas, and the other is the number of all the construction buildings.

TABLE IV
SPATIAL VARIABLES AND MODEL RULES

Variable Series IV	Statistic rule and proposal
Population density	average people per hectare in city region
Building construction	amount of buildings granted permits in both residential and non-residential

5. Environmental Dimension

Environmental factors are closely related to the industrial development, employment and living options. Here we select one representative urban pollutant and chose air pollution index as variable.

TABLE V
ENVIRONMENTAL VARIABLES AND MODEL RULES

Variable Series V	Statistic rule and proposal
Environmental Pollutants	concentration of one of air pollutants from sulphur dioxide, nitrogen monoxides, nitrogen dioxides or dust loading

In summary, we initially established a comprehensive evaluation variable system of Halle's shrinkage (Fig. 2).

Fig. 2 The concept structure of variables of shrinking Halle

B. Data Collecting

To ensure the final calculation results are accurate and

effective, it demands more requirements for collecting data. First of all, the paper covers the data in the time period between the 1990s and today, considering the impact of the political turnaround in 1989 and the German reunification in 1990. Second, the paper refers to the city of Halle as a whole; therefore, the paper uses mainly official municipal data [16]. Furthermore, official planning documents and other reports issued by the city of Halle are also considered, as well as scientific literature. Third and the most important, all above listed variables must ensure a continuous series of data and the total amount of date should at least be 15 years. Comprehensively consider the data collection requirements and the actual statistical data resources, the finalized data are from 1993 to 2010.

In order to test the final calculation, we also need to collect the total population growth at the same period as a measurement of urban shrinkage of Halle.

C. Data Processing Procedure

Basically the analysis has experienced four phases of data processing procedure according to the quality of data, the calculation rules and the testing standards.

1. Phase I: Data Filtering

In the first step of collecting data, because of some practical reasons we cannot find the statistic data or we found the data but they are not continuous, less than 15 years or lost specific years of data. We abandoned this part of data to ensure the quality of total data. These part of variables include aging population (over 65 years old), number of immigrants and emigrants, disposable income of private household. After first phase of data filtering, we acquired 5 categories of 19 variables from the year 1993 to 2010.

results because the correlation matrix is not Positive Definite Matrix, which means the calculation result is invalid. The main reasons for that might be comparing with the sample size of year (18), the number of variables (19) are comparatively more. Therefore, we excluded some variables in Common Factor Variance table whose values of Extracting are less than 0.9 (including Death Number, Number of Employee Sector 1, Number of employee sector 3, and Taxes). This means that correlation of these variables with shrinkage is not strong enough. After the screening process we have 15 variables left.

3. Phase III: Revised Calculation

Inputting the revised 15 variables' data into the software, the results showed that the KMO testing value is 0.652 (>0.600) and the Bartlett's sphericity inspection sig. is 0.000 (<0.05) which are all eligible. However, after the calculation we only generated two factors, which is not enough to summarize and explain the shrinkage reasons. So we excluded variables in figure Components of Rotating Space's four quadrants neither close to 1 nor -1 (including Expenditures and Short-term Residence). Now we got 13 variables.

4. Phase IV: Final Calculation

During this phase, we checked the variables again to see whether they comply with the actual situation or not. In this step, we added three more variables to complete the variable system, including the number of employees in sector 1 and 3 (only having sector 2 is not enough), as well as the number of short-term residence to compare with long-term residence.

Then we input all 16 variables' data and get eligible KMO and Bartlett testing results. Finally we got total three factors to represent 16 variables explaining the shrinkage of Halle (Table VII).

TABLE VI
DATA FILTERING RESULTS

Categories	Variables
Demographic (6)	· Birth Number · Death Number · Foreign Population · German Population · Short-term Residence(<5) · Long-term Residence(>15)
Economic (6)	· Gross Domestic Product · Number of Employee Sector 1(agricultural and forestry and fishing) · Number of Employee Sector 2 (manufacturing industry) · Number of employee sector 3 (others) · Expenditures · Taxes
Social (4)	· Crime Representation · Unemployed · Mean size of Household · Number of Students
Spatial (2)	· Population Density · Building construction
Environmental (1)	· Concentration of Environmental Pollutants

TABLE VII
FINAL CALCULATION RESULTS

Categories	Variables
Demographic (5)	· Birth Number · Foreign Population ·German Population · Short-term Residence(<5) · Long-term Residence(>15)
Economic (4)	· Gross Domestic Product · Number of Employee Sector 1(agricultural and forestry and fishing) · Number of Employee Sector 2 (manufacturing industry) · Number of employee sector 3 (others)
Social (4)	· Crime Representation · Unemployed · Mean size of Household · Number of Students
Spatial (2)	· Population Density · Building construction
Environmental (1)	· Concentration of Environmental Pollutants

2. Phase II: Initial Calculation

Inputting the entire data filtered in the first phase into SPSS software to conduct the first round of calculation. Preliminary calculations showed that there is no KMO and Bartlett testing

IV. RESULTS

According to the methodology application described above, we get the results of the model through four steps based on principal component factor analysis. In KMO and Bartlett's test of factor analysis, the KMO value is 0.615 (> 0.6), therefore it has a strong inter-correlation between variables. The Sig is

0.000 (<0.05), indicating that the original variables are independent with each other (Table VIII). The variables we selected qualified KMO and Bartlett's test, thus the result of factor analysis is acceptable.

TABLE VIII
SPATIAL VARIABLES AND MODEL RULES

KMO and Bartlett's test		Value
Sampling sufficient degree of Aiser-Meyer-Olkin measure		.615
Bartlett's test of sphericity	Approximate chi-square	541.287
	df	120
	Sig.	.000

After verifying the variables, we get the total explained variance table. It shows that 16 selected variables are extracted to three most representative factors. These three factors rotated cumulative variance reaches 92.827% (> 80%), which means that they can explain 16 variables well. The first factor is dominant among three factors. And it is able to explain 64% of the overall variables. Second and third factor values are 18.60% and 10.21% respectively. All 16 features factor values are shown in Fig. 3.
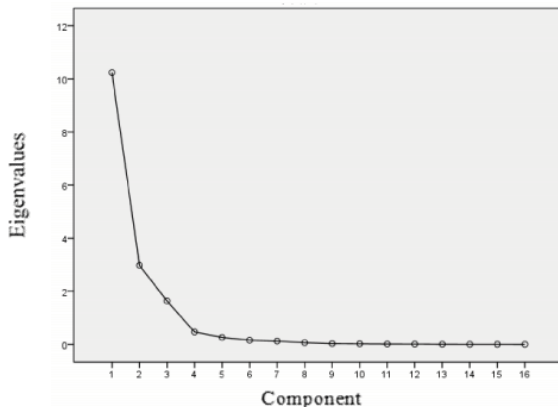

Fig. 3 Screen plot of factors' value

Table IX is rotated component matrix. It shows how 16 variables can be categorized into three factors. In the table each variable will have a value corresponding to three factors. And the larger absolute value of variable is, the greater it contributes to factor. In addition, positive number indicates a positive contribution to shrinkage, whereas negative number means negative contribution to shrinkage. The maximum value of each variable illustrates the certain factor group it should be classified into.

We can see that the factor 1 contains 9 variables (German population, population density, foreign population, pollutants, Gross Domestic Product, employee number of sector 2, size of household, birth number, number of students). Among these variables, German population, population density, pollutants, employee number of sector 2 and the size of household have positive effect on shrinkage, which coincides with population and manufacture decline in Halle since 1990. These 9 variables are basically related to population and economic development, so we denominate factor 1 Demographical & Economical

Factor.

Factor 2 contains 4 variables (unemployed, building construction, employee number of sector 1, crime representation). Since these variables explain unemployment, crime rate, housing demolition, we can name factor 2 as Social Stability Factor.

Factor 3 contains 3 variables (short-term residence, long-term residence, employee number of sector 3). Three variables illustrate population staying length and tertiary industry development, which shows the population movements and service level of Halle. So we name factor 3 as City Vitality Factor.

TABLE IX
ROTATED COMPONENT MATRIX

Variable	Factors		
	1	2	3
German Population	.968	.209	.052
Population Density	.968	.200	.102
Foreign Population	-.963	-.093	-.007
Pollutants	.951	-.104	-.170
Gross Domestic Product	-.950	-.265	-.049
Employee Sector2	.936	.294	.158
Size of Household	.907	.267	.292
Birth Number	-.903	-.211	.012
Number of Students	-.855	-.457	-.091
Unemployed	.094	.944	-.193
Building construction	.286	.837	.394
Employee Sector1	.540	.726	.222
Crime Representation	.627	.701	.226
Short Term Residence	.042	.139	-.944
Long Term Residence	-.202	.572	.771
Employee Sector3	-.307	-.191	-.754

Extraction Method: Principal component.
Rotation method: a Kaiser standardized orthogonal rotation method.
a. Turn after four iterations to converge.

Finally, we get a factor score table which shows three factors' contribution of demographic change from 1993 to 2010 (Table X). Similarly, the larger absolute value of score is, the greater it contributes to shrinkage. And positive number indicates a positive contribution for shrinkage, whereas negative number means negative contribution to shrinkage as well.

As seen from Table X, the overall trend of Demographical & Economical Factor from 1993 to 2010 is gradually reduced, indicating that demographic and economic factor stimulated Halle shrinkage at the beginning, but its role became less important later. After that, Social Stability Factor began to affect Halle from 1997 and it stopped having positive impact on shrinkage after 2004. Subsequently, City Vitality Factor began to affect Halle shrinkage from 2005. Thus, we find three historical shrinking stages in Halle as shown in Fig. 4.

V. DISCUSSION

The results of the study impressively show different factors' impact of the shrinkage process on Halle. After we analyze the results corresponding to Halle' data in the past decades, there are three aspects to discuss from the results.

We argue that three main factors contributing to Halle shrinkage, which are Demographical & Economical Factor, Social Stability Factor and City Vitality Factor. These three factors were respectively playing leading role in the three historical stages (Table X). Demographical & Economical Factor started to influence Halle because of the low birth rate and emigrant since 1990. Meanwhile, Halle's manufacturing industries began to decline. It interacted with the population reduction which led to Halle initial shrinking. Afterwards, due to the rise of unemployment, crime rate and housing vacancy, Social Stability Factor replaced Demographical & Economical Factor becoming the main factor of shrinkage from 1997. City Vitality Factor began to affect Halle shrinkage from 2005 as a result of low city vitality brought by poor attraction and outmoded tertiary industry.

There is an inner relation between three factors. In fact, Factor two and three are Factor one's lag response. Demographical & Economical Factor played as the initial motivation of shrinkage at the beginning. After population and economy recession, the unemployment and crime number rose and housing turned to vacant. For example, 26,000 of roughly 152,000 apartments in Halle were vacant in 2006. This process was also accompanied by a large amount of massive suburbanization trends and demolition in the inner city. Furthermore, globalization leads to the transformation of manufacture, which makes lots of industrial cities trying to become more competitive in global context and to achieve the transition of economy during post-industrial era. But previous unstable social environment in Halle makes it harder to attract people and investment, thus led to low city vitality.

Factors' trends suggest that Halle' shrinkage is slowing down, or even has stopped. As factor score table shows, all three factors' score are turning to be negative to shrinkage (Table X). Although this conclusion is different from some studies which argue that Halle would keep shrinking till 2020. Our result is approved by real data that at least from 2010 to 2013, Halle's population is growing every year from 230,377 in 2009 to 232,705 in 2013.
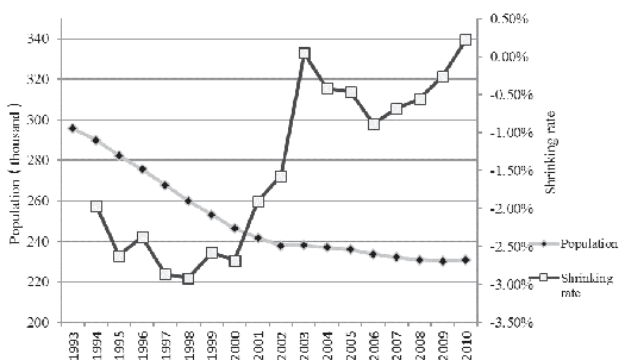

Fig. 4 Population and shrinking rate in Halle (1993-2010)

TABLE X
FACTOR SCORE TABLE

Year	Population	Demographical & Economical Factor	Social Stability Factor	City Vitality Factor
1993	295 741	2.31815	-.48908	-1.24251
1994	289 909	1.89578	-.42430	-.89007
1995	282 349	1.66285	-.85392	.86704
1996	275 604	.78745	.49982	1.25014
1997	267 776	.31781	1.14812	1.83971
1998	259 925	.03554	1.58076	.94474
1999	253 224	-.23351	1.54991	.19222
2000	246 450	-.25035	1.10536	-.24183
2001	241 710	-.38605	.61949	-.77728
2002	237 951	-.53042	.68850	-.99051
2003	238 078	-.56029	.45566	-1.27019
2004	237 093	-.81175	.36561	-1.87826
2005	235 959	-.81173	-.55881	.55534
2006	233 874	-.72747	-.77146	.46765
2007	232 267	-.61705	-1.25288	.67121
2008	230 900	-.68127	-1.14666	.46092
2009	230 377	-.72039	-1.21178	.19316
2010	230.831	-.68729	-1.30433	-.15147

VI. CONCLUSION

One aim of this paper is to make an empirical interpretation about the importance of the main changes in the city development directly related with the shrinking Halle. The other is to present a methodology through which we determines the most relevant factors that directly impact the city shrinkage.

Based on the research results, we need to establish a new perspective to face the problem of shrinking cities. Since the City Vitality Factor influences the shrinkage of Halle in recent years and probably in the coming decade, plus this factor possess mitigating function of shrinkage, decision makers should take the chance to make full use of it. For example, they should provide a better platform for small entrepreneurial or encourage innovation industry in order to promote the employment of services and high-tech industries or sustain the diversity of population and cultures in the city. In spatial planning, the government could transfer the large number of abandoned land and housing into green land or open space with recreational facilities.

In addition, broad engagement is essential for confronting city shrinkage. Meaningful and deep collaboration between businesses and citizens, stakeholders and government, public agencies and city planners may make the difference. Individual projects aim at economic growth and population retention, though targeted, are unlikely to change the trend of shrinkage. Halle and many other European shrinking cities should accept that the non-growth pattern of development is normal in today's context, thus they are supposed to shift from the growth-oriented perspective to realize that it is time to tap the potential of shrinking cities: they are smaller but they could be better.

According to the results and the demographic data of Halle, both of them show that Halle may no longer be the traditional shrinking city in the future. Therefore, we hope to do further research. For example, we are expected to answer whether the

three factors we found affecting Halle's shrinkage in last decades will still play their roles in reverse shrinking process of Halle. Besides, we also want to apply our method on some other shrinking cities, such as Leipzig, Detroit, etc. to test this method.

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