Case Study

Typology of Urban Shrinkage in Russia: Trajectories of Russian Cities

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Abstract: Most cities experience growth periods, leading to a population boom and to stagnation periods followed by population decline. Russian scientific literature uses terms such as *depressed*, *crisis*, *problematic*, and *waning* cities to describe the processes inherent to the phenomenon of shrinkage. To this day, there is no unanimity in the terms and definitions used, so each study sets its own criterion to define shrinkage. The current study aims to elaborate a growth-shrinkage typology of Russian cities, outline major shrinkage features, and answer the question of what might have initiated shrinking processes in the Russian Federation. The authors applied cluster analysis to 883 cities to study growth trajectories and decline over the last 30 years. Six types of cities were revealed: constantly growing, growing with stumbling, parabolic type, inverse parabolic type, continuous shrinkage after the year 1998, and continuous shrinkage after the year 1991. The main findings are that 73% of Russian cities have been experiencing shrinkage to various degrees, and only 27% are growing or have stood on the path of stable development recently. This study provides a better understanding of urban shrinkage in Russia, brings additional insights into the types of shrinkage of Russian cities, and fills the scientific literature gap. Current typology covers a broad range of Russian cities and could provide a new perspective on shrinkage problems in Russia. **DOI: 10.1061/(ASCE)UP.1943-5444.0000739**.

Author keywords: Shrinking cities; City typology; Russian cities; Urban decline.

Introduction

Recently, the phenomenon of urban shrinkage has become apparent worldwide. Scientists from Europe and the US started to investigate this manifestation of the city's economic and social lifecycle development as early as the 1980s (Ryan 2012). For 40 years, scientists explored the phenomenon of shrinkage mostly on the domestic level (Martinez-Fernandez et al. 2012). Now, we are witnessing broadening attempts to delineate patterns of shrinkage in previously unrepresented countries in the international arena (Batunova 2015; Haase et al. 2017).

Research on city shrinkage began in the 1980s; however, there is still no agreement on the definition of a shrinking city (Alves et al. 2016). Scientists often define a *shrinking city* as an urban area that goes through economic stagnation, loss of population, high unemployment rates, and social and demographic difficulties (Hollander and Németh 2011). *Urban shrinkage* is seen as a multifaceted phenomenon that affects all spheres of human life, from the economy to psychological aspects at both global and individual levels (Lee et al. 2016).

Russian scientific literature provides a complex definition of city shrinkage with various equivalents distinguished by the concept's focus. There are a plethora of definitions used by experts: *depressed cities* (depressivnie goroda) (Nikitin 2012), *crisis cities* (krizisnie goroda), *backward and problematic cities and regions* (problemnie i otstauschie goroda i regioni) (Liubovniy and Pchelintsev 1998), *unpromising cities* (neperspectivnie goroga) (Zinchenko 2017), and *fading and regressing cities* (ugosauschie goroda) (Vlasova and Grin 2015). Although, in recent years, *waning* and *shrinking* denotations spread across the scientific literature (Batunova 2017; Efremova 2018; Golubchikov and Makhrova 2013). Russian studies lack unity in understanding of the phenomenon, and a clear definition of cities that experience shrinkage is yet to be defined (Cottineau 2016).

Many international studies have developed diverse typologies of shrinkage to structure the reasons for population decline and provide strategies to mitigate it. However, the process of urban shrinkage and depopulation in the Russian Federation has an unprecedented scale (Cottineau 2016). In Russia, the urban shrinkage problem seems to spread at a deeper level, surpassing just shrinking/depressed cities, but scientists study the entire depressed territories and regions (Milchakov 2012; Surkova and Shusharina 2009).

This study represents an attempt to elaborate a county-wide typology of Russian growing/shrinking cities, because typology is needed for further assessment and forecasting. Although some shrinking city typologies have been presented in Russian scientific literature (Milchakov 2012; Surkova and Shusharina 2009), very few of them cover a wide range of cities and draw a broad picture (Cottineau 2016; Diappi et al. 2013). The current paper empirically studies the trajectories of Russian cities' development, including periods of growth and periods of decline connected with crisis

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milestones in the country. Because depopulation is considered one of the most revealing indicators of urban shrinkage (Alves et al. 2016), population change data from 883 cities in 30 years (1989–2018) have been analyzed, and six types of cities have been discovered. The developed typology with the identified tie on the economic component could, in the future, serve as the basis for managing the population decline problems faced by more than half of Russian cities.

Literature Review

Over the last few decades, scientists worldwide have been actively scrutinizing urban shrinkage and related processes (Breuste et al. 2015; Großmann et al. 2013; Martinez-Fernandez et al. 2012). Scientific literature delivers a diverse range of declining cities' typologies and classifications encompassed by the study depth, degree, and focus. Researchers develop typologies to structure the phenomenon of shrinkage and find solutions and approaches to address difficulties related to population loss.

In the international arena, authors distinguish types of cities depending on various factors. Some are based on the city's town-planning foundation: perforated and fragmented cities and transformed and dissolving cities (Göschel 2003). Others are built on the stage of decline and pace of population loss (Couch et al. 2005; Du and Xun 2018; Rybczynski and Linneman 1999; Wolff et al. 2017) or on policy reactions to shrinkage: trivialization, countering, acceptance, and urban decline utilization (Brown 2004; Weaver and Bagchi-Sen 2017). Other typologies are based on the opportunity to cope with the crisis related to shrinkage: consolidated cities, stabilized cities, stagnating cities, eroding cities (Hannemann 2004), and on shrinking cities' pull-and-push attributes (Artmann and Breuste 2015; Guimarães et al. 2016). There are typologies built on shrinkage causes: deindustrialization, suburbanization, globalization, and political or climatic transformations (Ding et al. 2015; Hollander et al. 2009; Pallagst et al. 2013; Turok and Mykhnenko 2007). Others are based on statistical location and city size (Ribant and Chen 2020).

For a significant number of Russian cities, economic stagnation, migration outflow of residents in search of job opportunities, and better education became an urgent problem (Plisetskii 2018). Today, the nature of modern demographic and economic trends suggests that population reduction will be the primary development trend for Russian cities in the long-term perspective (Trukhachev et al. 2020). Russian cities with negative population dynamics differ considerably in population, geographical location, and economic specialization (Chernyshev 2016). Thus, the exploration of population decline trajectories in most cities provides the opportunity for generalizing shrinking trends on the national scale (Kim 2019).

Despite the presence of shrinking city typologies in the Russian scientific literature, there is still no overall classification that would explore the totality of shrinking/growth trends in Russia (Milchakov 2012; Surkova and Shusharina 2009). Much scientific literature analyzes typological groups of small and mono-profiled recourse-based cities affected by population decline the most (Averkieva 2018; Gunko et al. 2019). The predominant theme is the study of the economic component of the city's development, with some attention to sociodemographic (Antonov et al. 2014; Milchakov 2012; Ponkratova et al. 2016; Vlasova and Grin 2015; Zinchenko 2017) and urban planning aspects (Gunko et al. 2020; Trukhachev et al. 2020). A very few broad typologies of Russian shrinking cities have been found (Cottineau 2016; Diappi et al. 2013).

Academic research in Russia focused on recourse-based cities, providing monoprofile resource-based cities typologies based on various perspectives. Milchakov (2012) developed a typology based on the city's investment activity, living standards, and long-term development trends (Milchakov 2012). Surkova and Shusharina (2009) developed typology using economic change and the industrial base state as indicators for affiliation with various types. Babaev and Lodishkin (2006) used the depth, vector, severity of the depression, and the territory's potential to develop small cities' typology in the Ivanovo region. A broader typology by Cottineau (2016) draws the separation criteria based on the correlation of natural balance and net migration accounting for most of the Russian cities and outlines three types of declining cities: shrinking, drifting, and depopulating. Diappi et al. (2013) explores 856 Russian cities and discovers 4 groups of cities: *urban engine*, *strong cities*, *dynamic cities*, and *weak cities*.

The preceding analysis of scientific literature suggests that the discourse on Russian national shrinking cities might be informed by the local political and economic trends and accounts for a narrow range of city and region types (Döringer et al. 2020). Broadening attempts denoted by foreign studies analyzing Russia's shrinking situation reaffirm the need for a broad, inclusive classification based on general standard criteria (Cottineau 2016).

Methodology

Current research is operationalized on the city level, with demographic change data as a critical indicator for describing shrinking cities (Bagchi-Sen et al. 2020; Wolff and Wiechmann 2018). After the USSR collapsed, the Russian Federation's new government structure provided much liberty for the federation subjects to manage their inner structural and socioeconomic issues. The criterion basis of city status allocation was also shifted to the hands of local policymakers. Local authorities in 85 federation subjects could decide what type of settlement should be considered a *city*. Before the research, the authors conducted a detailed analysis of local government regulations regarding the *city* status allocation. In the Russian Federation, the definition of *city* varies in different regions (Batunova 2017). Only 21 local governments out of 85 explicitly mentioned the required number of residents in the settlement to be more than 10,000 inhabitants in order for a settlement to gain city status, among other criteria. The rest of the local governments have assigned this number to be no less than 12,000 inhabitants, with some using 50,000 inhabitants as criteria. The others do not specify the exact numbers but explicitly itemize the existing cities in the federation subject's administrative-territorial structure. To achieve common ground in city evaluation, the authors have screened the existing cities, especially small ones, to consider the value and risks they could add to the research. The results show that the cities with less than 10,000 inhabitants are scarce. They also do bring a problem of data availability to the research. Existing population data in the federal bank of statistical data lack multiply data points regarding these cities' populations. Moreover, the local statistical bureau could also not provide the numbers for periods in time under the investigation.

Lastly, the authors calculated the median value for the existing city status allocation criteria and found out that it is 12,000 inhabitants. Finally, under our preliminary research result, we have decided to use 12,000 inhabitants as inclusion criteria in the analyses. The current study defines a shrinking city in line with previous research (Alves et al. 2016; Guimarães et al. 2013) and federation subjects' laws. The status of a *city* in different regions of Russia is assigned to the settlements of 10,000–12,000 people (Paramonova and Dulina 2015), with most of the population engaged in the nonagricultural sector. There are 1,115 settlements

in the Russian Federation with city status (Population of the Russian Federation by Municipalities 2020). There are cities whose population is less than 10,000–12,000 people, and their city status is associated with historical aspects and negative population dynamics of settlements that already had city status. For the cluster analysis described subsequently, each city's data are required with a maximum allowable gap of two points. Most cities with fewer than 12,000 people do not have available data for three or more consecutive years in a row and cannot be included in the primary analysis. Therefore, Russian cities with 12,000 inhabitants and more were included in the analysis (883 cities). Hence, based on international and domestic conceptualizations, the following definition of a shrinking city is used in the current study: a shrinking city is an urban area with 12,000 inhabitants or more that underwent a population decline during the last 10 years or longer. Because depopulation is one of the brightest indicators of shrinkage (Alves et al. 2016), population data in the years 1989–2018 of all cities whose population at the end of the period exceeded 12,000 people were subjected to cluster analysis. Statistical data were gathered for the demographic change of population of the respective cities starting from the year 1989 (the last USSR census) to the end of the year 2018. Data were collected from the official website of Federal State Statistics Service *Rosstat* and its regional branches (Federal State Statistics Service n.d.). The period was chosen for two important reasons. First, it is characterized by critical political and economic changes in the Russian Federation in the post-Soviet period when market relations replaced the planned economy, consequently changing existing technological structures and causing a profound transformation of the social and economic space (Gusev 2012). This period's study could provide additional insights for understanding the influence of economic and political changes on the population trajectories. Second, data availability concerns played an essential role in our decision for the study period. Demographic data before 1989 are not available for most small-sized cities and only partly available for medium-sized cities; therefore, the authors decided to consider only the last 30 years of Russian history with an abundance of data presented.

The authors first normalized the data and then used the k-means method (Jain 2010) to group trends into generalized groups. The implementation of the method in the statistical analysis program Statistica was used. The purpose of the k-means method is to divide m observations (from space R^n) into k clusters (a cluster analysis process). Every observation refers to that cluster, which is the closest to the center (centroid). The Euclidean metric is used as a distance measure. The authors have several observations ($x^{(1)}$, $x^{(2)}$, …, $x^{(m)}$), $x^{(j)} \in R^n$. In this study, the observations are trends for each city (the total number 883). The dimension n was 21. The distance to the centroid of the cluster is calculated by the principle

$$\rho(x, y) = \|x - y\| = \sqrt{\sum_{p=1}^{n} (x_p - y_p)^2} \tag{1}$$

where $x, y \in R^n$. The k-means method divides m observations into k clusters ($k \le m$) $S = (S_1, S_2, \ldots, S_k)$. The division helps to minimalize the total quadratic deviation of the cluster points from the center of these groups:

$$\min\left[\sum_{i=1}^{k} \sum_{x^{(j)} \in S_i} \|x^{(i)} - \mu_i\|^2\right] \tag{2}$$

where $x^{(j)} \in R^n$, $\mu_i \in R^n$, and μ_i is a centroid of the cluster S_i.

After determining the distance to the center, the partition of objects into clusters was reduced to determine these clusters' centroids. The authors set the k number of clusters in advance. In the study, the number of clusters ranged from 2 to obtain an interpretable result confirming a preliminary theoretical analysis. The metric minimization chart showed a significant decrease in up to six clusters. When the number of clusters was more than 6, the decrease was insignificant, so six clusters were chosen for further analysis.

In the first stage, the centroids of the clusters were chosen randomly. Observations are determined based on those clusters whose average is the closest to this group. Each cluster relates to only one observation. Then the centroid of each i-th cluster is recalculated according to the following rule:

$$\mu_i = \frac{1}{s_i} \sum_{x^{(j)} \in S_i} x^{(j)} \tag{3}$$

Therefore, the k-means algorithm consists of recalculating at each step of the centroid for each cluster obtained in the previous step. The algorithm stops when the values μ_i do not change during several steps or after completing a given number of steps. The authors used the second criterion, where the number of steps equal to 100 was determined during the preliminary launches.

Typology of Russian Cities

The authors analyzed 883 Russian cities over the last 30 years (1989–2018). The cluster analysis described in the preceding paragraph revealed six types of cities: (1) constantly growing; (2) growing with stumbling; (3) parabolic type (shrinkage after the year 1991 and fast growth after 2008); (4) inverse parabolic type (periods of intense and mild growth before 2005, and rapid shrinkage after 2005); (5) continuous shrinkage after the year 1998; and (6) continuous shrinkage after the year 1991 (Table 1). The authors calculated the centroid's distances for every city in the study to explore the cluster analysis results. The cities that were closest to the centroid in every cluster were taken to represent its cluster.

Constantly Growing Type

Sustainable population growth is traditionally regarded as an indicator of cities' successful development and attractiveness (Guimarães et al. 2016). It is assumed that *healthy* and prosperous cities attract population, showing a growth trend, while less *healthy* ones stagnate and even shrink, losing their population (Alves et al. 2016).

Only 8.9% of all analyzed cities can be attributed to the group of constantly growing (79 out of 883). No shrinking trends have been observed in this group during the whole study period. On the graph (Fig. 1), we see active population growth until the year 1998, a drop in growth during the year 1998 Economic Default period (Ponkratova et al. 2016), a sharp jump in population growth in the early 2000s, and finally a smooth subsequent growth until the end of the study period.

Table 1. Types of Russian cities

Type	Quantity	Percentage of the total
1. Constantly growing	79	8.9
2. Growing with stumbling	109	12.3
3. Parabolic type	52	5.9
4. Inverse parabolic type	63	7.3
5. Continuous shrinkage after the year 1998	255	28.9
6. Continuous shrinkage after the year 1991	325	36.7

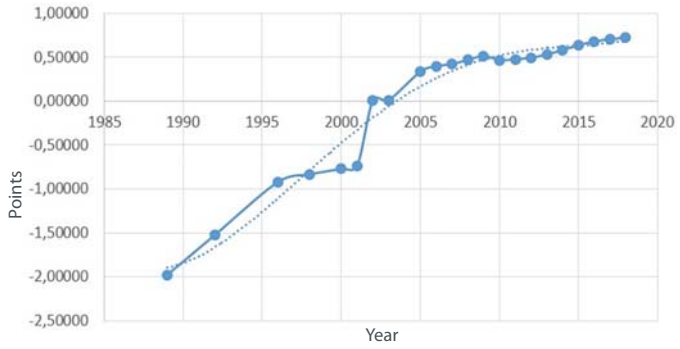

Fig. 1. Constantly growing city-type trend chart.

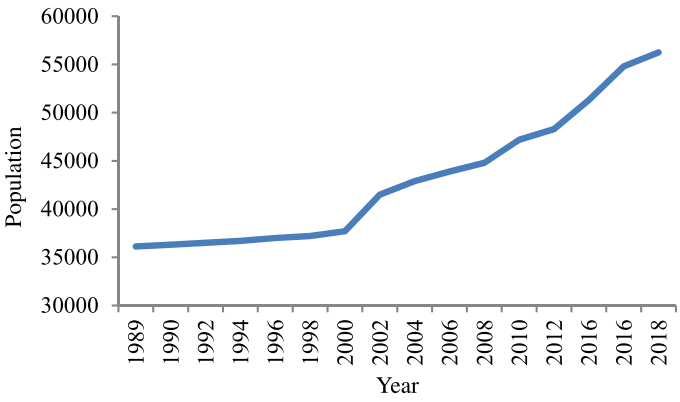

Fig. 2. Typical trajectory of a constantly growing city (on the example of Dzerzhinsky city, Moscow region).

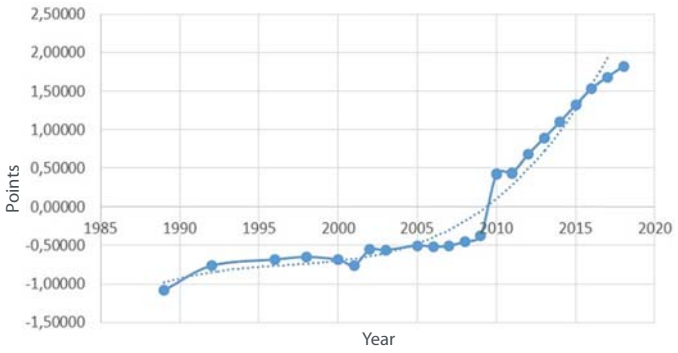

Fig. 3. Growing with a stumbling city-type trend chart.

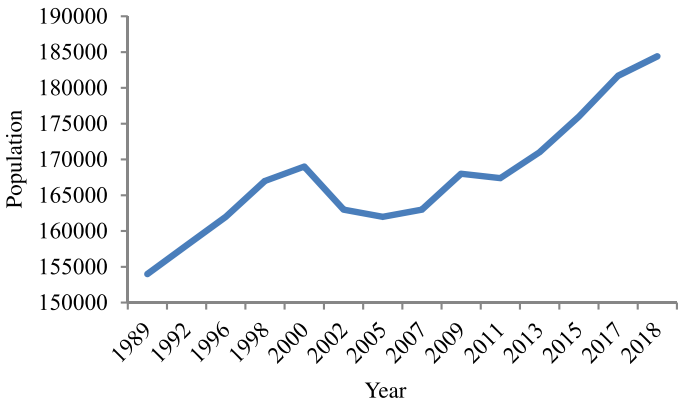

Fig. 4. Typical trajectory of a city growing with stumbling (on the example of Abakan city, the Republic of Khakassia).

This group contains cities showing a continuous increase of inhabitants, despite the overall political and economic restructuring. As an example, consider the city of Dzerzhinsky, Moscow region. During the period under review, the city's population grew systemically, and since the year 1989 (36,108 people) has grown by 55.8% and in 2019 totaled 56,257 people (Fig. 2).

Growing with Stumbling Type

Not all growing cities managed to maintain stable growth rates during periods of crisis in the country. Some growing cities met holdups on the development path due to the city's individual characteristics (location, size, and the level of development) and external factors (the general economic and political situation in the country). This indicates a lack of organization and a possible beginning of stagnating tendencies. The general characteristic of cities in this category is a significant increase in the population during the period under review, despite periods of population decline. This group consists of 109 cities (12.3% of the total). On the trend graph of this city type (Fig. 3), the authors observe the following: weak population growth in the period up to 1998, a small failure during the Economic Default of the year 1998, then a weak population growth until the year 2009, a sharp increase in the year 2010, the second period of negative dynamics in the year 2011, and finally stable energetic population growth until the end of the study period.

The sharp increase in the year 2010 is likely due to the influx of populations from smaller cities, which suffered more during the crisis of the year 2008 (Popikov 2016). The stumbling periods vary in different cities, but most of them coincide with the crises of the years 1998 and 2008. The rest falls on the individual problems of a single city: change of owner at a city-forming enterprise, terrorist attacks or military actions, and natural and artificial disasters (fires, floods, accidents, and explosions in mines).

For example, the authors considered the city of Abakan, the Republic of Khakassia (Fig. 4). In the period 1989–2018, the population increased by 17.5%, while there was a stumbling block in growth after the year 1998, which reflected in a decline of the population from the year 2000 to the year 2009. In the following period, population growth was stable.

Parabolic Type

The parabolic city type is less common than the others (5.9% of the total). However, the following paths of shrinkage and growth are visible on the trend chart. These cities are characterized by a rapid decline in population after the collapse of the Soviet system in the year 1991, stable development, and a rapid increase in the number of inhabitants after 2008 (Fig. 5).

It would seem that the year 2008 was a turning point for the worse for many Russian cities due to the World Economy Crisis (Popikov 2016), and such stable development in crisis conditions is illogical. However, the Russian government has developed a number of support measures and paid particular attention to regions with difficult economic conditions—the Arctic and the far North, the far East (Uporov 2018). In respect of these regions, additional measures were applied to prevent out-migration and ensure citizens' social protection. Cities in which state support and good governance at the regional level coincided were included in a period of stable development (Chernyshev 2016). The *Maternity Capital* federal support program was established in the year 2007. The

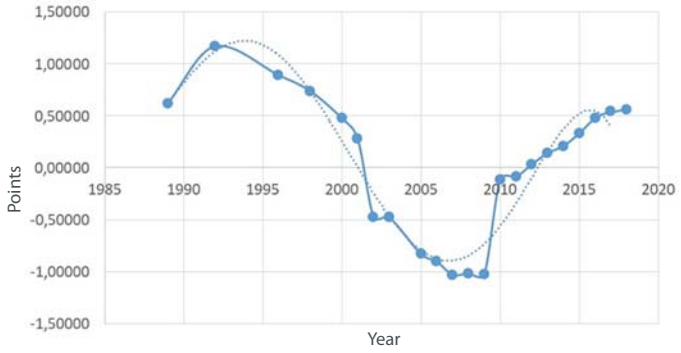

Fig. 5. Parabolic city-type trend chart.

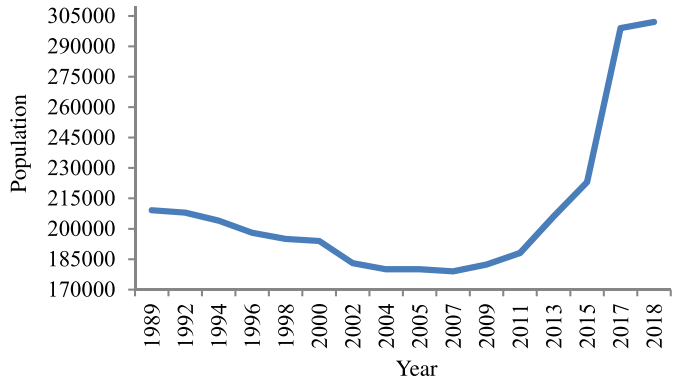

Fig. 6. Typical trajectory of a parabolic-type city (on the example of Podolsk city).

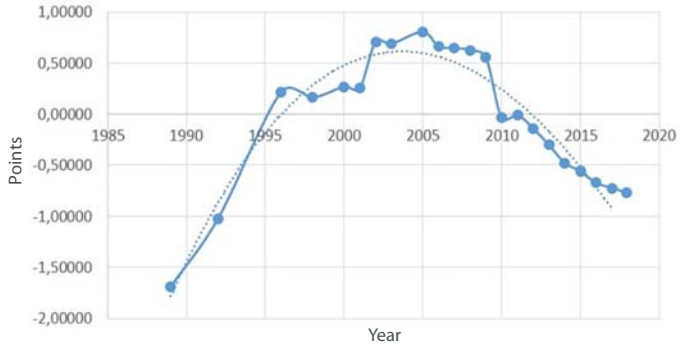

Fig. 7. Inverse parabolic city-type trend chart.

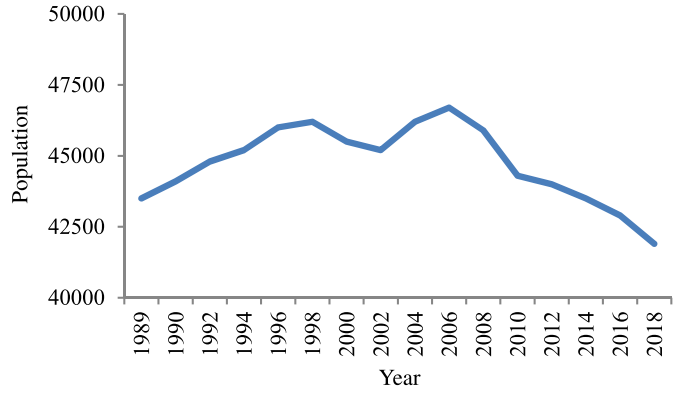

Fig. 8. Typical trajectory of an inverse parabolic type (on the example of Shebekino, Belgorod region).

essence of the *Maternity Capital* program is to provide one-time financial aid to absolutely all mothers (single or married, or fathers/legal guardians in the event of a mother's death) to citizens of the Russian Federation in the amount of 453,026 rubles (the amount is about 6,200 US dollars) at the birth/adoption of the second child (or the following child, if the family already had two or more children at the time of the establishment of the program). This amount cannot be cashed out but can be used to pay off a mortgage payment, purchase housing, improve housing conditions, and in several other cases, clearly stipulated by the program. The program has been successfully operating since the year 2007. Although the program aims to stimulate the birth rate, not cope with the shrinkage of particular cities or regions, positive consequences for the population decline situation since 2007 have been observed in many cities of Russia. In 2007–2014, there were significant positive changes in the total birth rates (Svetlichnaya and Menschikova 2017). Many experts believe that the Maternity Capital program is one of the most effective measures to solve the country's demographic problems (Velieva and Gulivich 2020).

A striking example is the city of Podolsk (Fig. 6). The number of inhabitants systematically decreased since the year 1989 (2,07,000 people) and in 17 years (1989–2007) lost almost 30,000 people (179,400 people in 2007). Since the year 2008, the population has increased rapidly, and over the last 10 years, it has enlarged by more than 1,00,000 (3,04,245 in 2018).

Inverse Parabolic Type

The inverse parabolic group includes 63 cities, which is 7.3% of all cities under study. Cities in this group have common shrinkage features: a relatively sharp population decline occurs in the periods (one or several) around 1998 and 2008. Short periods of population decline indicate that cities of this type are on the appropriate path of development, can function, and cope with crises fast (Bakanov 2005). However, susceptibility to crisis phenomena reveals weaknesses in the city management structure.

Cities of this type have been visibly struggling with shrinkage. The cluster analysis revealed a trend chart of the city type named *inverse parabolic* due to visible resemblance. The trend chart shows a general population growth with an approximate peak in 2005 and a decline in active growth in the late 1990s, and a general tendency toward shrinkage since the mid-2000s (Fig. 7). Even though the number of inhabitants in some cities of this type has not declined during the study period but grew up to 9%, these cities should, by definition, be classified as shrinking.

Consider a city of inverse parabolic type on the example of Shebekino, Belgorod region (Fig. 8). Shebekino is a small town with less than 50,000 inhabitants. The city has seen a steady population growth until the year 1998. Then there was a short period of decline and subsequent growth until the year 2005. From the year 2005 to the end of the study period, the city's population has been systematically decreasing.

Continuous Shrinkage after the Year 1998 (1998 Shrinkage)

The economic crisis of the year 1998 in Russia was one of the worst in Russia's history (Ponkratova et al. 2016). Cities, where relative stability was observed in the difficult post-Soviet transformation period, revealed their inability to cope with the new crisis.

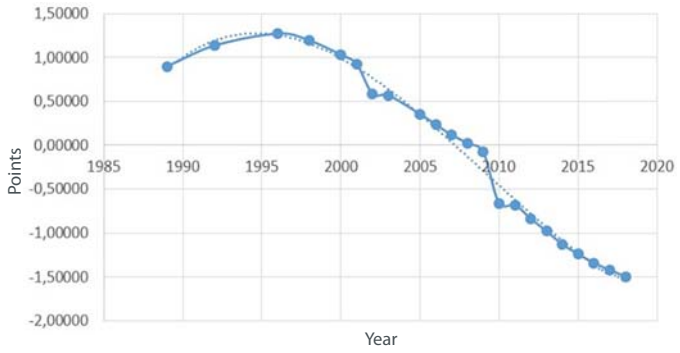

Fig. 9. 1998 Shrinkage city-type trend chart.

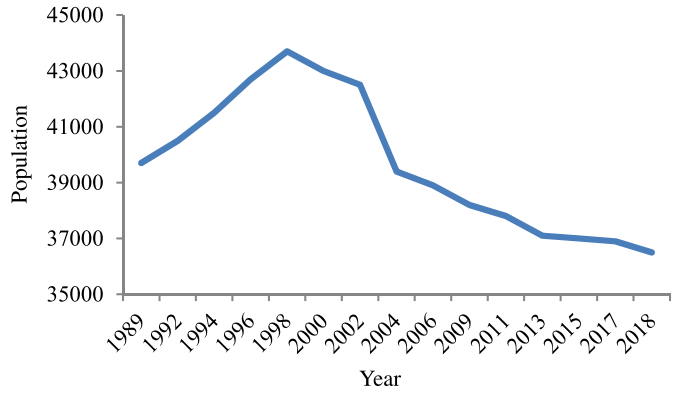

Fig. 10. Typical trajectory of a 1998 shrinkage city type (on the example of Sharypovo city, Krasnoyarsk region).

This city type's trend chart is characterized by a relatively stable development and population growth until 1998 and tangible, rapid depopulation after the year 1998 (Fig. 9). Most cities in this group are small cities.

Sharypovo city is a typical example of a 1998 shrinkage city type. From the moment of its foundation in the year 1959 to the year 1998, the city showed stable population growth, despite the country's political crisis. However, after the year 1998, there has been a steady decline in the population (in 1998–2018, the population decreased by 16.5%) (Fig. 10). The main industrial profile of the city is coal mining. The economic crisis of the year 1998 directly affected the volume of coal production, which led to significant wage cuts, staff reduction in the enterprise, and an outflow of population from the city.

Almost one-third of all cities (255 out of 883, 28.9% of the total) belong to this type, which designates the economy's high instability to crisis changes (Milchakov 2012).

Continuous Shrinkage after the Year 1991 (1991 Shrinkage)

The extreme outflow of population from cities coincided with social and demographic changes caused by the fall of the Soviet system (Bakanov 2005). This group of cities is the largest group with shrinking trends identified in the research process. Out of 883, 325 cities belong to this type, which is 36.7%. Most cities of this type are small cities, which are the most unstable during periods of crisis.

The trend chart clearly shows (Fig. 11) a stable decrease at the beginning of the 1990s, and a sharp drop in the early 2000s, followed by the same stable shrinkage.

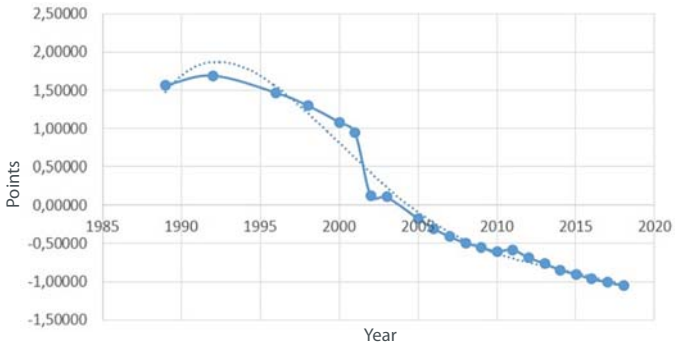

Fig. 11. 1991 shrinkage city-type trend chart.

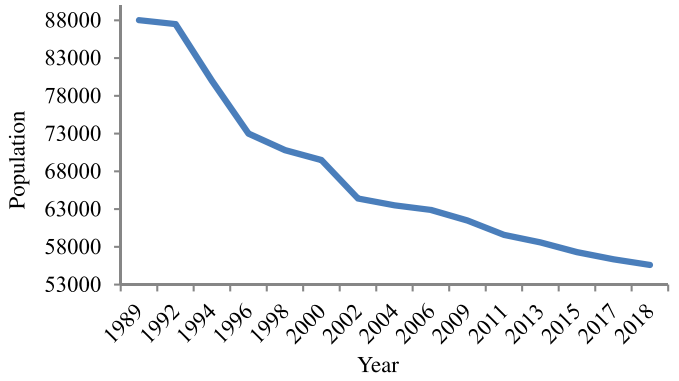

Fig. 12. Typical trajectory of a 1991 shrinkage-type city (on the example of Apatity city, Murmansk region).

Cities of the 1991 shrinkage type have been declining systematically, and during the study period, have lost 10%–56% of the population. The example of the Apatity city in the Murmansk region clearly shows shrinking trends (Fig. 12). The population of the city reached its peak in the year 1989 and amounted to 88,089 people. In 30 years, the population has rapidly declined, and in the year 2018, it fell by 37.1% and dropped to 55,413 people.

Discussion

The current study analyzed 883 Russian cities. The results show that 643 of them are continuously shrinking (73% of a total, fourth, fifth, and sixth city type) and have lost a significant part of its population in 30 years (1989–2018); 240 cities are stably growing (27% of a total, first, second, and third city type).

Russian cities are classified according to the number of inhabitants as follows: small (≥50,000 residents), medium (50,000–1,00,000 residents), big (1,00,000–2,50,000 residents), large (2,50,000–1,000,000 residents), and largest (more than 1 million people). Several facts related to the size of cities were outlined in the process of this study.

Table 2 demonstrates the distribution of cities by size in six city types. There are 603 small-sized cities, 125 medium-sized cities, 83 big cities, 57 large cities, and 15 largest cities. Small- and medium-sized cities are mainly shrinking (501 and 84, respectively). There are 44 growing big cities and 39 shrinking big cities. The large and largest cities are mainly growing (39 and 14, respectively).

Fig. 13 graphically shows the distribution of cities by size and types. Most of the large and largest cities are in groups of growing cities, while the prevalent number of small- and medium-sized

Table 2. City-type and city-size distribution

City type	City type	City size				
		Small	Medium	Big	Large	Largest
Growing	Type 1	39	17	19	2	2
	Type 2	39	17	21	25	7
	Type 3	24	7	4	12	5
Shrinking	Type 4	46	13	4	0	0
	Type 5	205	32	17	1	0
	Type 6	250	39	18	17	1
Total		603	125	83	57	15

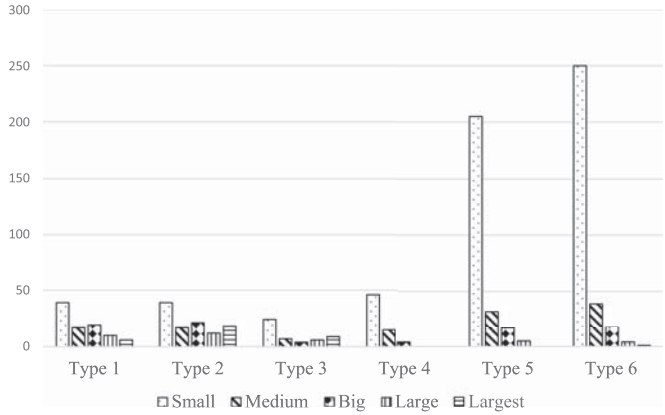

Fig. 13. City-type and city-size distribution.

cities fell into the shrinking type (fourth, fifth, and sixth types). Big-sized cities are distributed approximately evenly in growing and shrinking city types. An interesting fact could be seen in Type 6: there is one largest city that falls into the 1991 shrinkage type. Nizhny Novgorod city is the only constantly shrinking largest city in Russia. During the study period, the number of the city's inhabitants dropped by 12.8% (more than 1,80,000), and in the year 2018, it was 1,253,511 inhabitants. All other largest cities are growing.

The study has revealed a connection between population fluctuations and economic crisis periods. The beginning of shrinkage for Russian cities was set during the USSR period (Milchakov 2012). Further, the USSR fall has provoked severe economic and political changes that affected the population and increased mortality, population outflow, and lower birth rates in many Russian cities. Many cities could not resist rapid and drastic changes in politics and economics and entered the path of depressive development and stagnation (Bakanov 2005). The political system's crash, followed by the economic transformation to market relations, ceased the federal support and cut the investments. Consequently, cities had to cope with the crisis using limited regional budgets (Milchakov 2012). Big cities adapted to the market conditions better, so did regions and cities with resource-producing industries and branches of the first redistribution, whose products were in demand by the world market. These cities have mostly formed two growing city types.

Regions and cities that specialized in the manufacturing industry were, as a rule, less competitive due to increased competition with imports and a reduction in the demand for defense products. In the crisis of the 1990s, these regions and cities, especially resource-based and mono-profiled ones, experienced the most substantial and most prolonged decline in production, investment, employment, living standards of the population, and consequently, population decline (Gusev 2012). Most of these cities belong to the 1991 shrinkage type, and only a few have managed to come out of crises and turn into parabolic type.

The next stroke shook the country in 1998 when one of Russia's worst economic crises took place (Ponkratova et al. 2016). The crisis occurred against the backdrop of a difficult economic situation in the country, aggravated by the inefficient macroeconomic policies pursued by the authorities in the mid-1990s. The economic Default of the year 1998 dealt a massive shock to the country. Many cities that managed to survive the transformations of the year 1991 were no longer able to cope with the crisis and went into a decline (Milchakov 2012). Therefore, the Default played a crucial role in the 1998 shrinkage city-type formation.

Further, the economic growth of the 2000s partly mitigated shrinking trends in depressed cities and regions by the economic upgrade and the redistribution policy of the federal authorities. Additional support measures and extra consideration to regions with a depressed economy (Uporov 2018) have played a partial role in the formation of a parabolic city type.

Then, the crisis of the year 2008 highlighted the socioeconomic instability of many regions and cities again (Antonov et al. 2014). More problematic regions and cities were those in which the economy's crisis recession coincided with the post-Soviet period's long stagnation trends (Efremova 2015). The economic crisis of 2008 became a fractional basis for the inverse parabolic city-type formation.

Several issues that are not the scope of this study are proposed for further research: (1) taking into account the population density, the percentage of decreasing cities in the southern regions of the country is much lower than in the central part of Russia, in the North, and in the Far East; therefore, further research on shrinkage, geographic location, and climate influence is required; (2) to benefit a data range and to provide an understanding of the development trajectories of shrinking Russian cities, it is necessary to extend the studied time period and analyze shrinking trends before the year 1991; (3) a precise study of each shrinking type is needed for the identification of possible subtypes, their features, and particular drivers of shrinkage; (4) future research on urban shrinkage in Russia could be further enriched by using economic data and demographic processes on city and regional levels; and (5) there is a need for an investigation of transport infrastructure. In line with Wolff and Weichmann (2018) and Diappi et al. (2013), all these could give a better understanding of shrinkage processes and account for demographic and economic changes in society.

Conclusion

The cluster analysis exposed itself as a valuable tool for investigating a wide range of Russian cities, systemizing the data, and building population trajectories of growth and shrinkage. Based on the *k*-means method application, the analysis has discovered six urban trajectories of modern Russian cities (constantly growing, growing with stumbling, inverse parabolic, parabolic, 1998 shrinkage, and 1991 shrinkage). The current paper has revealed a considerable disproportion of growing and shrinking cities. The population trajectories of Russian cities showed the majority of shrinking trends (73% of all studied cities).

Various factors influence the shrinkage process (Martinez-Fernandez et al. 2016), and economic factor is one of them. The results of the analysis show a connection between economic degradation and depopulation. No doubt other factors took place in the processes of population decline; nevertheless, the economic factor comes to the fore in Russian cities. Each city type demonstrates a link to crisis events and cities' reaction to the population

fluctuations. This knowledge can be crucial to the development of a shrinking city, because this can lead to more effective strategies for maintaining and even increasing the population.

Current typology overlaps with the typologies proposed by Cottineau (2016) and Diappi et al. (2013) and in addition demonstrates the connection of economic decline and shrinkage. Further studies on (1) the identification of subtypes and gradations within each group; (2) shrinkage/growth factors; and (3) management mistakes and mitigating projects are needed. Therefore, future research ought to focus on finding ways to strengthen the flexibility and enhance shrinking cities' sustainability.

Data Availability Statement

Some or all data, models, or code generated or used during the study are available from the corresponding author by request.

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