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CITIES' SUSTAINABLE DEVELOPMENT: REVEALING INTERPROJECT SYNERGIES AND TRADE-OFFS AND MAKING THEM MANAGEABLE

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Abstract. The city's strategy should take into account not only the priorities of increasing investment competitiveness and the improvement of citizens' well-being, but also the issues of sustainable development. Sustainable development of cities has been the subject of active discussion in recent years. This article proposes four modernized directions for sustainable urban development, which correspond not only to the UN Sustainable Development Goals (SDGs) (particularly SDG 11), but also to the original directives of local authorities.

These directions include affordable housing, accessible and sustainable transportation systems, sustainable urbanization, and the environmental impact of cities. We developed a methodology for estimating synergies and trade-offs between and within these directions using correlation network analysis with the causality of the indicators and the lags of years. We tested this methodology by estimating the synergies and trade-offs in the sustainable development of the thirteen largest cities between 2015 and 2019. The results of the correlation network analysis are offered as a weighted directed network correlation graph. Our findings could be implemented by local authorities in the form of a Gantt chart for the optimal order of sustainable urban developmentthat could be based on the network correlation graph.

Keywords: sustainable development, synergy and trade-off, affordable housing, sustainable transport, sustainable urbanization, correlation network analysis.

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Introduction

City management authorities perform a variety of functions ranging from economic development of the city and increasing its investment attractiveness to overcoming poverty and demolishing slums. Local authorities should pay attention to the city's slums, the frequency of traffic congestion, the level of environmental pollution, etc. It is important to monitor these spheres retaining them at an acceptable level.

The deterioration of urban problems will inevitably lead to degradation and economic downturn of the city. In this regard, the focus of our research is to determine the indicators of these spheres that characterize the directions of the cities' sustainable development (CSD).

The variety of the CSD programs could have positive and negative effects on each other. These are phenomena of "synergy" and "trade-off".

For example, various measures that improve the sustainability of urbanization and the transportation system involve comprehensive land use in urban planning. On the contrary, the expansion of housing and road construction leads to a reduction of green areas and a deterioration of the ecological situation in the city.

Corresponding situations in various areas of sustainable development often have been observed by the researchers and policy-planners. Synergy and trade-offs are currently the most relevant issues of recent research in the implementation of sustainable development goals.

This research examines the synergies and trade-offs for the national programs of the SDGs. There are only a few examples of exploration of the SDGs synergies and trade-offs at the city level.

This study fills a gap in the literature by investigating the synergies and trade-offs as systemic interconnections between different directions of the CSD. Our research will allow local authorities to correct or adjust urban policies by choosing measures that enhance the synergistic effect or mitigate the negative externalities.

We begin by elaborating the directions and indicators of the CSD. After collecting a database of indicators of the largest Russian cities development in the period between 2015 and 2019, we identified potential synergies and trade-offs between them using a network correlation graph. Finally, we filled in the Gantt chart of the optimal order of the CSD projects.

Literature Review

Indicators of Sustainable Development at the City Level

The CSD can be investigated from three different perspectives. A case-study of the CSD could be conducted as a longitude research of a single city development (Hu, Geertman, 2018; Yue et al., 2014). The second focus of the CSD analysis could be a group of cities in a particular region of a country (Tran, 2016; Xu, Mingxue, 2020; Yang et al., 2020). However, the majority of authors analyze different directions of sustainable development in the largest cities of a country to suggest some regulations and control policies for sustainable urban development and to investigate the driving forces for urban sustainability change (Fan and Qi, 2010; Strzelecka, 2008; Tai, Xiao, 2020; Yang et al., 2017; Rama, 2021).

In our research we follow the approach of investigating the largest cities in the country. The largest cities are comparable in size, population, and economic welfare. The compatibility of the cities allows us to focus on the evaluation of sustainable development.

Previous research has shown that the three dimensions, i.e. economy, ecology and social sphere (Elliott, 2006; Marcuse, 1998; Portney, 2013; Satterthwaite, 1997) are too broad to constitute effective indicators of sustainable development at the city level. Thus, there is a need to identify city-specific indicators to measure sustainable development in cities. To be more precise, recent research exploits "GDP per capita" as the most appropriate indicator of economic development and the standard of living in a city. The "air quality standard" and the "urban greening coverage" are environmental indicators, while the "rate of urbanization" and "education expenditure as proportion of GDP" are social equity indicators (Fan and Qi, 2010; Moroke, 2019; Tai, Xiao, 2020; Xu, Mingxue, 2020; You, Shi, Feng, 2020; Yang et al., 2020; Rama, 2021).

Major drawbacks of exploiting the concept "Economy, Ecology and Social development" for the CSD is that it envisages an administration of institutional and financial opportunities that are beyond the "influence zone" of local authorities. For example, local authorities have limited indirect influence on economic growth in the city or unemployment rates, because they do not produce goods and services themselves. They only develop an institutional environment, propose measures of public support, and ensure the protection of the rights of manufacturers and entrepreneurs.

Discussing the "power" of local authorities, it is important to consider the basic directions of Urban Economics: Land Use, Transportation, Public Finance, Housing and Environment (O'Sallivan, 2019; Duranton et al., 2014, 2015). The CSD could be managed by focusing on these spheres that are in an immediate "influence zone" of municipal authorities.

These circumstances have been instrumental in shifting urban research attention to sustainable transportation systems, housing, urban environmental impacts, accessible and green public spaces, etc. For instance, You et al. (2020) underline that human development, urbanization, and transportation accessibility are the most concentrated directions of the CSD. Many attempts have been made to focus on ecological indicators that reflect the quality of life in the city (Tran, 2016), waste reduction (de Guimarães et al., 2017), sustainable housing (Winston et al., 2008), sustainable living infrastructure (Fischer & Amekudzi, 2011), sustainable well-being (Costanza et al., 2016), and social innovation initiatives (Angelidou, 2017). Some studies offer a classification of indicators used for the CSD assessment (Huovila et al., 2019; Ameen, 2019).

According to the Urban Economics Concept, a direct transition of the UN Sustainable Development Goals to the city level seems to be based on unsupported assumptions. For example, in most countries, SDG 1 "No Poverty", SDG 2 "Zero Hunger", SDG 3 "Good Health and Well-being", SDG 4 "Quality Education" and SDG 5 "Gender Equality" are implemented at the national level within the relevant directions supporting social policies. Subsequent SDG 8 "Decent Work and Economic Growth", SDG 9 "Industry, Innovation and Infrastructure", SDG 10 "Reduced Inequalities" and SDG 12 "Responsible Consumption and Production" require significant financial support at the national or regional level and, accordingly, could not be set as the objectives for local authorities. Other goals relate to environmental protection and the development of alternative energy sources that also require the accumulated efforts of the neighboring regions and even countries.

This discrepancy between the indicators of the CSD, on the one hand, and the competencies of the local authorities, on the other hand, determines the need to focus only on narrower areas of the CSD, than those listed in the UN Sustainability Goal no.11.

The indicators that reflect a modified approach to sustainable development allow us to identify seven directions of sustainable development of cities and societies (Sustainable Development Goal 11 "Sustainable Cities and Communities"):

- Ensure access for all to adequate, safe, affordable housing and basic services and upgrade slums;
- Provide access to safe, affordable, accessible and sustainable transportation systems for all, and improve road safety;
- Enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management;
- Increase efforts to protect and safeguard the world's cultural and natural heritage;
- Significantly reduce the number of deaths and people affected and substantially decrease the direct economic losses caused by disasters as a proportion of global gross domestic product;
- Reduce the adverse per capita environmental impact of cities;
- Provide universal access to safe, inclusive and accessible, green and public spaces.

However, among these areas from the point of view of Urban Economics Concept (and the immediate "influence zone" of municipal authorities) the City Administration can only have a mediation influence. So, the target "Strengthen efforts to protect and safeguard the world's cultural and natural heritage" suggests a nationwide policy and the target "Significantly reduce the number of deaths and the number of people affected by disasters" involves joint efforts in health and emergency prevention at the national and regional levels.

Thus, we suggest the following directions of the CSD according to the UN Sustainability Goal no.11:

– Level of access for all to adequate, safe, and affordable housing and basic services;
– Level of access to safe, affordable, accessible, and sustainable transportation systems for all citizens;
– Level of inclusive and sustainable urbanization and human settlements planning and management;
– Level of overcoming the negative environmental impacts of cities.

Nevertheless, the choice of indicators of the CSD is not the ultimate goal of our research. The most important thing is to determine how to assess synergies and trade-offs between these directions of the CSD.

Synergies and Trade-offs of Sustainable Urban Development Goals

The terms "synergy" and "trade-off" are used in different disciplines and imply different research methodologies . In our research, we use the following definitions. "Synergy" is a situation in which actions aimed at improving one sector of the CSD have a positive spillover on the development of another sector of the urban economy. "Trade-off" is a situation in which actions aimed at improving one aspect of the CSD significantly reduce the effectiveness of measures in another sector of the urban economy. The concept of trade-off suggests a strategic balance between these local policies to reduce the overal diminishing effect.

Many authors provide qualitative approaches to the study of synergy and trade-offs. Some research identify only a potential synergies and trade-offs between SDGs by visualizing them using schemes of phenomena interdependence (Felappi et al., 2020; Nerini et al., 2018; Singh, 2020), pie charts (Maes, 2019; Nerini, 2018), or colored bar charts (Philippidis et al., 2020), and even scenario analysis (van Vuuren et al., 2014). Researchers have also applied a point scoring to investigate the mutual influence of different directions of sustainable development (Nilsson et al., 2016; Fader et al., 2018; McCollum et al., 2018; Sachs et al., 2019; Weitz et al., 2018). However, qualitative methods reflect only expert opinion, and are not supported by objective data.

The second, quantitative approach to assessing SDGs synergy and trade-offs aims to overcome this problem and is based on quantitative assessment methods. Initial research on this approach focused on Luukkanen (2012). Most recent research also investigate synergy and trade-offs based on pairwise correlations (Mainali, 2018; Maes et al., 2012; Pradhan et al., 2017; Hegre et al., 2020; Zhong et al., 2020; De Neve and Sachs, 2020; Bennich et al., 2021; Alemu et al., 2021). Correlation can be supplemented by scenario modeling (Shi et al., 2021). One of the modernized forms is the network correlation analysis method that includes eigenvector centrality and betweenness centrality, and automatic community detection algorithms (Swain and Ranganathan, 2020).

When implementing national and local policies, it is important to develop data-driven decisions. The consequences of the realization of previous public policies can be estimated using advanced statistical methods. This will prevent mistakes in subsequent planning.

In this regard, our study, focuses on quantitative methods and develops for local authorities to plan the CSD. Our research of synergies and trade-offs is based on a correlation network analysis with causal relationships that occur with certain time lags.

Methods

The directions of monitoring sustainable development of cities

To estimate a progress of the CSD in the four directions (listed above) it is important to use more than one indicator listed in the official UNDP List of Proposed SDG Indicators (for SDG 11 "Sustainable Cities and Communities") (Final list of proposed Sustainable Development Goal indicators, 2016). We use the following three indicators for each direction:

1. Access for all to adequate, safe, and affordable housing and basic services:
   - 1.1. Average total area of residential premises per inhabitant, sq.m (the indicator is calculated as the ratio between the total housing stock at the end of the year and the resident population at the sametime);
   - 1.2. The share of households that do not consider that they experience significant constraint in their housing conditions, % (this indicator is the inverse of the original indicator calculated by comparing the area of living space in an apartment and the number of residents (also an assessment is made in comparison to the minimum social norms of living space per person);
   - 1.3. The share of the population that received housing and improved housing conditions in the reporting year out of the total population registered as needed housing, % (the indicator is calculated based on the number of residents (registered as in need) who received housing and improved living conditions);
2. An access to safe, affordable, accessible and sustainable transportation systems for all citizens:
   - 2.1. The reduction in the number of people killed in road accidents compared to the previous year, per 1000 people, (the indicator is calculated as the difference between the baseline and the number of traffic fatalities per 1000 people in the previous year;
   - 2.2. The share of roads that meet regulatory requirements, % (the percentage of local roads where the surface quality meets the technical requirements of Russian legislation);
   - 2.3. The density of local public roads, km per hectare (the indicator is calculated as the length of local roads divided by the total area of the city).
3. The level of inclusive and sustainable urbanization and human settlement planning and management:
   - 3.1. The ratio between the rate of the commissioning of housing and the rate of population change (the indicator is calculated as the annual increase in the area of new residential buildings in the city divided by the annual population growth);
   - 3.2. The area of land allocated for construction, per 10,000 inhabitants hectares (the indicator is calculated on the basis of the records of official local authorities about the decisions on the provision of land plots);

3.3. The share of the area of land plots that are subjects to land taxation in the total city area, % (the indicator is calculated on the basis of local authorities records on property tax).

4. The level of overcoming the negative environmental impacts of cities:

4.1. The volume of solid communal waste removed per year, m^3 per person (the indicator is calculated based on the volume and mass of the removed municipal solid waste);

4.2. The share of collected and neutralized pollutants as a percentage of the total amount of pollutants emitted from stationary sources, % (the amount of captured (neutralized) air pollutants includes all types of pollutants captured (neutralized) in dust- collection facilities (gas-cleaning) installations from the total amount of pollutants emitted from stationary sources);

4.3. The share of green areas in the total area of the city, % (the indicator counts the gardens of residential areas, microdistricts, boulevards, squares, green yards, areas of schools, kindergartens, plantings on streets and squares, etc.).

Some of these indicators were borrowed directly from the UNDP Official List of Proposed SDG Indicators (for SDG 11 "Sustainable Cities and Communities") or were subjected to minor adjustments – 3.1., 4.1., 4.2., 4.3. For the first direction "Level of access for all to adequate, safe, and affordable housing and basic services" we had to adapt and expand the indicator that is used in UNDP Official List. Indicators 1.2. and 2.1. were adapted from Eurostat analogs. To investigate access to affordable housing (indicators 1.1. and 1.3.), sustainable transportation systems (indicators 2.2. and 2.3.), and sustainable urbanization (indicators 3.2. and 3.3.), we used three additional indicators that better reflect the situation in Russian cities.

To compare the values of the indicators in various cities, the absolute values per 1,000 inhabitants or per unit area of the city were recalculated.

According to the Urban Economics Concept, these directions of the CSD are interrelated:

– Land Use: the city area is limited (to a certain extent) and can be used for housing and industrial construction, transport infrastructure, and green spaces – an increase in housing construction (indicator 3.2) leads to the reduction of road density (indicator 3.3.) and green spaces (indicator 4.3);
– Transportation: road safety (indicator 2.1.) largely depends on the quality of the road surfaces (indicator 2.2.); road density (indicator 3.3.) and the number of vehicles in the city leads to a deterioration of air quality in the city (indicator 4.2.);
– Housing: intensive housing construction (indicator 3.1.) leads to improvement of living conditions (indicators 1.1.-1.3.);
– Public Finance: intensive housing construction (indicators 3.1 and 3.2) also leads to an increase in local budget revenues from land tax (indicator 3.3.);
– Environment: increased urbanization revealed in the improvement of living conditions, the number of vehicles and the density of built-up areas, leads to an increase in municipal solid communal waste (indicator 4.1.), a deterioration of air quality (indicator 4.2.) and a reduction in green areas (indicator 4.3.).

Having decided on the list of indicators of the CSD, we proceed to the explanation of the methodology of synergy and trade-offs evaluation.

The methodology of synergies and trade-offs evaluation between and within the directions of cities' sustainable development

The design of the synergy and trade-offs evaluation for the CSD indicators is based on Correlation network analysis.

Network analysis was developed by adding the Granger causality analysis (Granger, 2001). It allows us to determine which indicator is the cause of the other. In accordance with the Granger test, two linear regressions are constructed for each pair of indicators. The obtained statistical significance of the estimates of the indicators of one regression from the pair allows us to determine causality. In addition to the standard Granger test, we chose the number of years of lag that exists between the change in the influencing variable and the dependent variable. Thus, we constructed six regressions for one-year, two-year, and three-year lags using the collected dynamic panel data of the indicators and evaluated the lowest p-value (Fraser, 2017) for the influencing variable. Since the cities vary in size and the data have a panel structure, the covariance matrix estimation proposed by Newey and West was used to adjust the standard errors to the conditions of heteroscedasticity and autocorrelation (Newey and West, 1987). It matters because in the other case the problem of heteroscedasticity and autocorrelation would not allow us to determine the statistical significance of the study. Using the described methods we were able to determine which indicator has an impact, which is dependent, and also to find out the most significant influence lag.

$$y_t = a_0 + a_1 y_{t-L} + a_2 x_{t-L} \quad (1)$$

$$x_t = b_0 + b_1 x_{t-L} + b_2 y_{t-L} \quad (2)$$

where y_t and x_t are potential dependent indicators, y_{t-L} and x_{t-L} are the same indicators with the lag of L, a_2 and b_2 are the regression coefficients which pass the statistical test.

For each pair of indicators with the lowest p-value determining the direction of influence, less than the p-value threshold of 0.05, their correlation was calculated. The graph is drawn using the Kamada-Kawai algorithm (Kamada and Kawai, 1989). The application of the algorithm is necessary for a visual representation of the graph. Thus, we define "the synergy effect" as a positive correlation between two indicators and "the trade-off effect" as a negative correlation.

Data collection

To assess the level of sustainable development of the largest Russian cities, data were collected reflecting the development of 13 largest cities in Russia (with a population of more than 1 million people): Novosibirsk, Yekaterinburg, Nizhniy Novgorod, Kazan, Chelyabinsk, Omsk, Samara, Rostov-na-Donu, Ufa, Krasnoyarsk, Perm, Voronezh, and Volgograd. The two largest cities in Russia, Moscow and St. Petersburg, were excluded from the sample due to their special status as federal cities and the related significant differences in municipal statistics.

To collect the necessary indicators of the CSD we used the database "Regions of Russia. Indicators of Russian cities" (Rosstat), a database of indicators of municipalities (Rosstat), data available on the official websites of cities and regions, and data from the traffic police website. The period under review is from 2015 to 2019. Thus, the collected data were converted into dynamic panel data.

Results

We estimate the synergies and trade-offs in the sustainable development of the thirteen largest Russian cities (Figure 1) during the period from 2015 to 2019 using the correlation of these panel data.

Figure 1. **The Russian cities with a population of more than 1 million.**

The Figure 1 presents the 13 largest cities in the Russian Federation with a population of more than one million (excluding the two largest cities of federal significance Moscow and St. Petersburg). As illustrated, three of them are located in Siberia, four – in the Urals, three – in the Volga region, two – in the south of the country and one – in the central part of the country.

The results of the correlation network analysis can be presented as a weighted, directed graph that can reflect synergy and trade-off effects as shown in Figure 2.

The analysis of the correlation network shows the synergies between the CSD indicators. For example, the growth in the provision of housing (indicator 1.1.) in 3 years is accompanied by an increase in the share of the land plots that are subjects to land taxation (indicator 3.3.). This contributes to the growth of municipal budget revenues and expansion of opportunities for financing new projects and programs for the development of the city.

We also detected two trade-off cases. For example, the growth in the provision of housing (indicator 1.1.) in 2 years reduces the need for new housing construction and the allocation of land plots (indicator 3.2.). This limits the growth of urban area and the scale of the destruction of the environment.

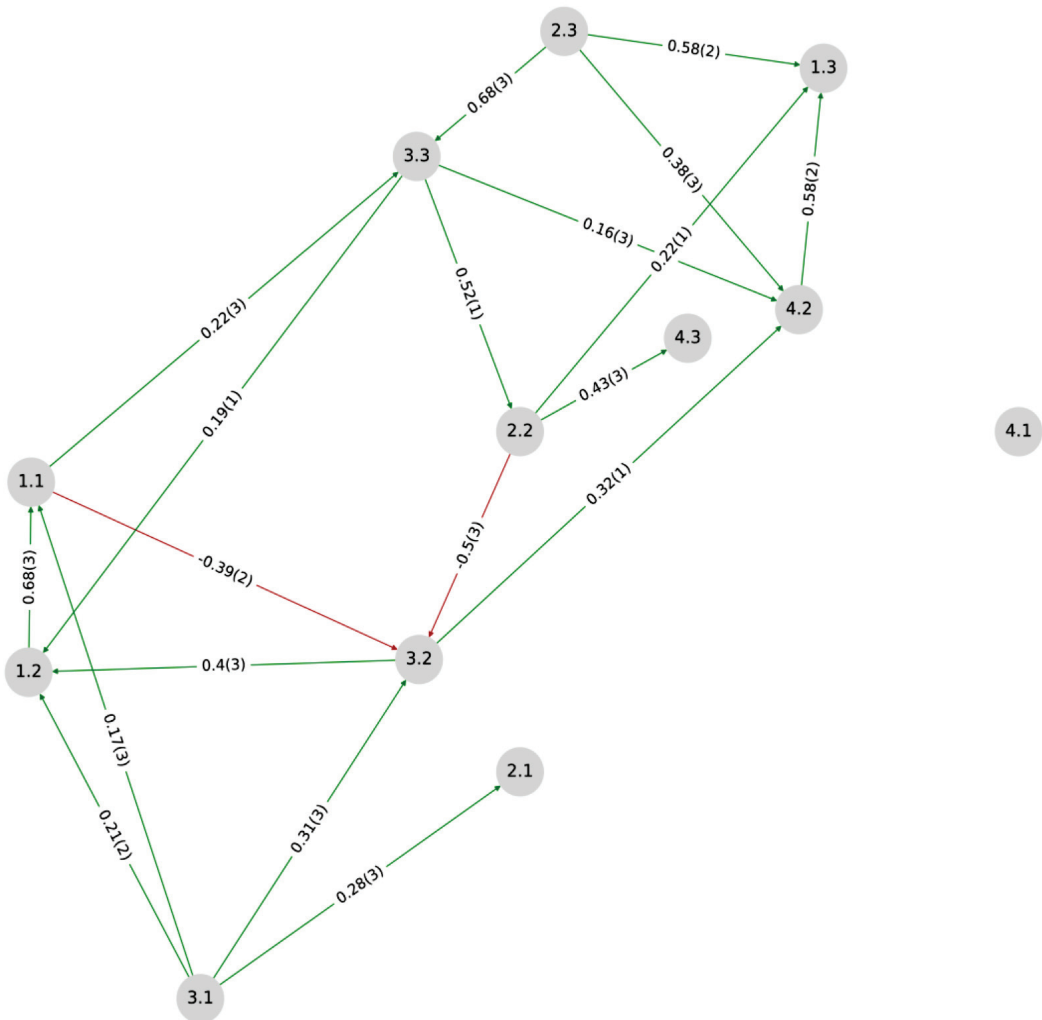

Figure 2. Network correlation diagram **of sustainable development indicators.**

The nodes of the graph are the indicators. The directed edges of the graph correspond to the relationships between the indicators, where the direction determines the impact of one indicator on the other ones. The color of the edge shows positive and negative correlation. The positive effect is shown in green, the negative – in red. Also, a numerical correlation value is indicated at each edge.

In general, the results of the correlation network analysis can be interpreted as "points of synergy concentration" and can also be used to develop the optimal order of the CSD programs. As presented in the network correlation diagram, projects of increasing indicators 1.2. (3.1., 3.2. and 3.3.), indicator 1.3. (2.2., 2.3. and 4.2.) and indicator 4.2. (3.2., 3.3. and 2.3.) could accumulate maximum synergy effect and could be "points of synergy concentration". For example, to increase the availability of adequate housing, it is important to ensure the preparation of land plots and the issuance of building permits (indicator 3.2.). In about 3 years, it will be possible to increase the share of citizens who do not in their housing conditions (indicator 1.2.).

If a year after beginning the project of land preparation, the intensity of housing construction in the city maintains the optimal pace (in comparison with the rate of population growth) (indicator 3.1.), the synergy effect will help to increase the share of citizens who do not feel constrained in their housing conditions (indicator 1.2.).

The second interpretation of the network correlation diagram is the development of the optimal order of projects for the sustainable growth of cities. This sequence is substantiated by the experience of the Russian cities investigated.

It is important to plan the relevant activities in a specific sequence to take advantage of the potential synergies. Moreover, local authorities have to take into account the identified time delay (1, 2 or 3 years) to achieve maximum synergy. On the other hand, since the measures of increasing indicator 2.2. diminish the efficiency of improvement an indicator 3.2., the CSD program must first implement measures to improve indicator 3.2., and then implement measures to improve indicator 2.2. The same applies to indicators 1.1. and 3.2.

The optimal sequence of actions to improve each indicator can be presented in the form of a Gantt chart (Table 1). This sequence was developed "to maximize synergy for indicator 1.2.". To achieve this goal, the projects to improve the indicators 3.2., 3.1 and 3.3 started sequentially in series with the interval of 1 year (in the 1st, 2nd and 3rd years, respectively).

The following sequence of the projects was developed according to the network correlation diagram. We assume that the city budget uses a three-year project schedule.

The optimal sequence includes ten years of projects on the CSD (in the spheres that we defined). The projects of the indicators of each group are presented in the same color palette.

The description of this chart requires also the clarification of some aspects:

- Strengthening the influence (coefficient of correlation) of indicator 1.2. on 1.1. more than strengthening the influence of 3.1. on 1.1., it means that a project to improve indicator 1.1. needs to be realized not in the 5th, but in the 7th year;
- A project to improve indicator 2.2. should be implemented after the project to improve indicator 3.2., and, therefore, should be planned only in the 4th year;
- A project to improve indicator 3.2. should be renewed in the 5th year, when a supporting effect of a project to improve indicator 3.1. appears;
- A project to improve indicator 3.3. should be extended in the 6th year, when a supporting effect of a project to improve indicator 2.3. appears; after that this project should be renewed in the 10th year, when a supporting effect of a project to improve indicator 1.1. appears;

Table 1

Optimal order of the projects of city's sustainable development

Projects/Years	1	2	3	4	5	6	7	8	9	10
3.2. Increasing an area of land allocated for construction					…					
3.1. Increasing the ratio between the rate of commissioning of housing and the rate of population change										
3.3. Increasing the share of the area of land plots that are objects of land taxation in the total city area						…				…
2.3. Increasing the density of local public roads										
2.2. Increasing the share of roads that meet regulatory requirements										
1.2. Increasing the share of households that do not consider that they experience significant constraint in their housing conditions										
1.1. Increasing the average total area of residential premises per inhabitant										
1.3. Increasing the share of the population that received housing and improved housing conditions in the reporting year out of the total population registered as needed housing									…	
4.2. Increasing the share of collected and neutralized pollutants as a percentage of the total amount of pollutants emitted from stationary sources										
4.3. Increasing the share of green areas in the total area of the city										
2.1. The reduction in the number of people killed in road accidents compared to the previous year										
4.1. Increasing the volume of solid communal waste removed per year										

– A project to improve indicator 1.3. should be extended in the 9th year, when a supporting effect of a project to improve indicator 4.2. appears; etc.

These synergies and trade-offs allow us to select the necessary tools that simultaneously have a positive effect in multiple directions of the CSD that reduces costs and allows more effective use of the city budget. The implementation of the correlational network analysis showed its consistency in identifying synergies and trade-offs in key areas of the CSD. The application of the Optimal order of the CSD programs could be a demanded tool for local government decision making.

Conclusion

We have outlined four directions of the CSD that are not only based on the UN Sustainable Development Goals, but also correspond to the Urban Economics concept. These directions are more consistent with the initial "influence zone" of municipal authorities. We have expanded the list of indicators for these directions of the CSD compared to the list established for UN SDG Goal 11.

The concept of synergy and trade-offs used in our study was also redefined. We used pairwise correlation (Pradhan et al., 2017; Hegre et al., n.d.; Zhong et al., 2020; De Neve and Sachs, 2020), but we used its modernized form – network correlation analysis, which was also used earlier by Swain and Ranganathan (2020). In addition to their methodology, we implement one-year, two-year and three-year lags for correlation pairs in our panel data.

In our research, the previously described methods of network analysis were developed by adding the Granger causality analysis (Granger, 2001) and modernized following Fraser (2017).

The results of the correlation network analysis are presented as a weighted directed network correlation graph that reflects synergies and trade-offs between and within the four directions of the CSD. The network correlation graph allowed the Optimal order of the CSD projects (in the form of a Gantt chart) to be created. This optimal order of the projects can be used for direct planning of the CSD.

The authors see a further improvement of this methodology in the application of correlation network analysis to determine not only the optimal sequence, but also the optimal duration of projects in each areas. Nevertheless, to conduct such an analysis , data on the duration of projects (that have already been implemented) will also be required.

It is also possible to apply the correlation network analysis to the analysis of sustainable development of medium and small cities in Russia. But the list of sustainable development indicators must be adapted for medium-sized cities, as the problem areas have a different focus.

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