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Economic Determinants of Smart and Sustainable Urban Development: What Answers Does the Cities in Motion Index Give?

Małgorzata Mańka-Szulik, **ORCID:** https://orcid.org/0000-0002-5328-8736
PhD, Silesian University of Technology, Poland
Vitaliia Koibichuk, **ORCID:** https://orcid.org/0000-0002-3540-7922
PhD, Associate Professor, Sumy State University, Ukraine
Anna Mogilina, **ORCID:** https://orcid.org/0000-0002-2743-3717
MS, Sumy State University, Ukraine

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Corresponding author: Małgorzata Mańka-Szulik, malgorzata.manka-szulik@polsl.pl

Abstract: *The goal of the article is to determine which components of sustainable and smart development of urban areas are the most important for the economy of a city. For this, regression, cluster and discriminant analysis are applied, using the data of the ranking positions of 180 cities of the world according to the Cities in Motion Index (CIMI) and its components for 2022. The Stata and Statgraphics 19 software packages are used for the calculations. The statistical significance of the input data is confirmed using descriptive statistics, and the normality of the data distribution was determined according to the Shapiro-Wilk test. A regression analysis (based on the least squares method) of the influence of the integral value of CIMI and its components (Human capital, Social cohesion, Environment, Governance, Urban planning, International profile, Technology, Mobility and Transportation) on its first component – Economy, is carried out. It testifies that only four indicators have a statistically significant impact: Cities in Motion, Environment, Urban planning, and International profile. Multiple regression, constructed using the strict screening procedure, confirms these findings; and discriminant analysis proves that the regression equation coefficients is used to predict the Economy variable. Analysis of Spearman's and Kendall's correlation matrices prove a close relationship between the Economy, Human capital, Governance, and Cities in motion; direct dependence between Cities in motion and such indicators as Technology, Urban planning, and International profile; average direct connection between Economy, Social cohesion and Mobility and transportation. Cluster analysis using the k-means method in the R Studio software environment made it possible to distinguish eight clusters of cities according to their ranking positions in relation to various parameters of the CIMI index (their number was calculated according to the Sturgess formula, and the optimality of their number is confirmed by the agglomeration scheme according to the Ward method). For the cities of the first cluster (17 cities, 9.44% of the total number analyzed, mostly world capitals), Cities in motion has the greatest impact on the Economy component, while Mobility and Transportation has a lesser impact; for the cities of the second cluster (23 cities, 12.78%, mostly large cities of the United States and China) it is Technology that has the greatest impact; for cities of the third cluster (35 cities, 19.44%, primarily powerful regional centers)it is Cities in motion, International profile, Mobility and transportation, Social cohesion, and Urban planning; for clusters four (9 cities, 5%) and five (6 cities, 3.33%), the regressions are not significant, so these clusters require further study for each city separately; for the cities of the sixth cluster (33 cities, 18, 33%, mostly developed European cities) the most important are Cities In motion, Environment, Governance, Mobility and transportation, Social cohesion, and Urban planning; for the cities of the seventh cluster (10 cities, 5.56%) – Human capital, Social cohesion, and Technology; for cities in the eighth cluster (47 cities, 26.11%, mostly cities facing economic obstacles to their development) – Cities in motion, Environment, Technology, and Urban planning. The discriminant analysis shows that the Environment indicator has the greatest impact on the division of clusters into groups.*

Keywords: Cities in Motion Index, smart city, sustainable urban development, economy, human capital, social cohesion, environment, governance, urban planning, technology.
JEL Classification: E59, E50, E40.

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INTRODUCTION

In the conditions of rapid urbanization and technological progress, the Smart city concept becomes more and more relevant. Smart cities demonstrate an innovative approach to the management and development of the urban environment, which is based on the use of advanced technologies and data to improve citizens' efficiency, sustainability and quality of life. The development of smart cities is critical to addressing the many challenges facing today's cities, such as growing population, overburdened infrastructure, environmental challenges, and social inequality. By integrating digital technologies, the Internet of Things (IoT), big data analytics and other innovative solutions, smart cities can optimize the use of resources, improve service delivery and provide a more inclusive and sustainable urban environment. In addition, smart cities have significant potential to stimulate economic development and create new opportunities for business and innovation. Thanks to the development of innovative ecosystems and the attraction of investment and talent, smart cities can become engines of economic growth and increased competitiveness at the global level.

Smart city is that kind of a city that prioritizes the well-being of its residents, focuses on urban growth, and uses information and communication technologies in the process of local governance, which involves joint planning and citizen involvement. By promoting integrated and sustainable development, smart cities increase their capacity for innovation, competitiveness, attractiveness and sustainability, which ultimately leads to an improvement in the quality of life of their residents (Flanders Investment & Trade, 2023).

As the implementation of information and communication technologies in cities and urban space gains momentum, interdisciplinary connections of the smart cities concept are rethought and filled with new content (Giffinger, 2010). Smart cities are traditionally associated with sustainable development and living conditions in modernized cities: readiness of their information and communication technologies, accessibility and standards of public transport, communication with other cities and states, access to health care, quality education, and other leisure activities.

One of the characteristics of smart cities is rational management, which involves better use of technology to align management processes with people's needs. Smart governance is usually considered a key element of the overall level of functioning of a smart city (Hello Lamp Post, 2023). To ensure the effectiveness of smart city management, all components of the local management system must be "smart". The "smart" management of the city is also facilitated by the introduction of Smart Payments systems that guarantee safe and fast transactions, the use of digital solutions in all areas of the organization of city life, from health care to education and security, the use of open data management systems and city analytics to make more effective decisions based on updated and accurate information (Enel X., 2024).

Modern digital data collection, storage and processing systems in smart cities increase decision-making efficiency. It helps monitor and rationally manage resources (Cocoflo, 2023).

Effective data collection also helps identify key issues and challenges faced by urban dwellers, leading to life-enhancing solutions in the future. To make data collection as simple and convenient as possible for all residents, smart cities use a variety of data collection sources, including sensors, IoT devices, mobile apps, and more. With the help of the obtained data, it is possible to reveal data on the city's vital activities, such as energy consumption, air quality, citizen feedback, information on waste management, etc. Robust data collection processes, in turn, ensure data integrity, reliability, and privacy protection (Ayanda, 2024).

In this context, the reliable storage of structured information collected over many years, including demographic data, property, infrastructure, public services, and other urban databases, becomes especially important. Reliable data storage allows for timely data review, determining long-term trends, planning future development, and efficiently allocating resources (The Role of Data Storage in Smart City Operations, 2024).

A crucial component of Smart city is smart mobility – smart and sustainable mobility solutions, smart city traffic management tools and efficient transport infrastructure. The development of modern technologies, such as geolocation, mobile technologies, electric cars, hybrid vehicles, etc., in smart cities allows for reduced traffic and increased mobility. Also, it provides many benefits to citizens and the economy (O'Brien, 2023).

By collecting data on traffic flows, traffic, road conditions, etc., the governing bodies, together with the residents of smart cities, manage to solve problems related to road congestion.

Among the main tasks related to security in cities are the reduction of terrorist attacks, improvement of cyber security, provision of physical and public safety, protection of personal information, and others. To achieve these goals, smart cities actively implement automated fire detection systems, artificial intelligence, video surveillance systems, the Internet of Things, and others (CORDIS, 2024).

The application and service development field continues to develop in smart cities. Among the largest companies providing Smart city software development services, the following can be distinguished: Innowise, Suffescom Solutions Inc, Softeq, ScienceSoft, and KiwiTech. They develop traffic, security, public transport programs and others (Tarn, 2023).

LITERATURE REVIEW

The increasing number of cities, identified as smart cities, that adopt smart development strategies, along with the growing amount of statistical data on the development of such cities and reports on surveys of their residents, generates increasing interest from researchers. It, in turn, leads to a rise in the number of scientific publications dedicated to various aspects of smart city development.

The "smart city" concept is developed to create an urban environment that enhances society's well-being and quality of life through improved efficiency of public services and infrastructure using digital technologies. Nowadays, society demands not only improved current well-being but also care for future generations. Therefore, smart cities must incorporate sustainability into their development and evolution. The book chapter by Carro-Suárez et al. (2023) aims to assess the impact of digital technologies implemented in smart cities on the social, environmental, economic, and institutional dimensions of sustainable development. The goal is to promote urban development that is both smart and sustainable, using globally recognized evaluation indices as a reference.

A smart city is a multifaceted concept that can be examined from various perspectives. E-governance is crucial for integrating all elements of a smart city. The article by Kuzior et al. (2023a) aims to explore the key enablers of e-governance through economic, social, political, information, and technological indicators. The study examines 68 smart cities chosen based on diverse regional affiliations and varying economic, social, and political development levels. The authors employ cluster analysis to group smart cities by e-governance indicators, construct an integral indicator using a linear mathematical model and the Fishburn formula, and use VAR/VEC modelling to analyze key factors influencing e-government development in smart cities. The research reveals that the Human Development Index significantly impacts e-governance, while the GNI per capita shows no influence across all clusters. Information technologies are identified as the primary direct influence on the Smart City Governance Index for the first cluster of smart cities, which have the highest e-governance indicators. Kenger, in 2023, uses clustering algorithms based on smart city development index data and demonstrates that clustering cities using expert assessments is less effective than using clustering methods. Cantuarias-Villessuzanne (2021) analyzes the smart strategies of European cities using clustering of smart cities based on the actions these cities undertake. The obtained clusters allowed for identifying various smart city development strategies: cities with new smart strategies, international megacities employing technology-oriented strategies to address specific issues, and medium-sized cities with a high quality of life. The article by Kusior at al. (2023b) utilizes a method involving the analysis of contemporary solutions in Smart Cities from academic literature and online sources. Its objective is to highlight potential threats that could emerge within Smart City societies, an issue of significant importance that the article thoroughly explores. Through extensive literature review, the authors propose the following insights: as modern technologies are implemented, careful consideration is crucial due to potential adverse effects. It is essential to establish comprehensive guidelines for each instance to mitigate these potential negative consequences and implement preventive measures against adverse effects from the introduction of new solutions.

The aim of the research of Kuzior et al. (2022) is to evaluate cities' resilience to the COVID-19 pandemic based on their "smart city" characteristics. The study employs several research methods: first is bibliometric analysis to identify primary research trends concerning "COVID-19" and "smart city" in Scopus publications from 2019 to 2022; second is k-means clustering to discern common patterns among smart cities regarding their preparedness and responsiveness to COVID-19; and third is correlation analysis to uncover relationships between smart city performance indicators and the severity of COVID-19 within these cities. According to the findings, smart cities exhibit greater preparedness for COVID-19 and lower fatality rates. However, they show weaknesses in the resilience and sustainability of their healthcare systems.

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The concept of a smart economy has emerged within the framework of smart cities to foster urban growth in today's digital society. However, amidst technological and economic shifts driven by globalization, cities are now challenged to sustain productivity while promoting sustainable urban development. Pajilani et al. (2022) aimed to define the smart economy within a smart city context and analyze its elements in Pengerang. The study employed a mixed-method approach involving questionnaires, document reviews, and observations. Findings indicated that respondents comprehended the smart economy concept, which facilitates and stimulates economic activity in Pengerang. The study also identified future strategies and initiatives to further promote the smart economy. The implications highlight the importance of paying attention to government-proposed issues and strategies for implementing and advancing the smart economy towards smart city status.

While existing literature extensively describes various projects and leading cities, there is a notable scarcity of systematic research into the reasons behind differing levels of advancement among cities. Cities are often considered as singular entities with strong geographic roots, implying that spatial and socio-economic contexts, which are recognized as primary drivers of organizational innovation, may significantly influence cities. Duygan et al. (2022) examined 22 Swiss cities engaged in smart city projects, employing fuzzy-set Qualitative Comparative Analysis to identify the combination of factors that differentiate cities in their smart city development. The findings suggest that a combination involving a high share of the service sector, presence of research institutions, and high urban density is sufficient for achieving advanced smart city outcomes. Conversely, factors such as population size, new residential development, and participation in international networks were found to be less critical. By shedding light on the spatial and socio-economic foundations of smart city progress, this study enhances our understanding of the geographical dynamics shaping smart cities.

The global patterns of urbanization vary across continents, necessitating diverse approaches, policies, and strategies. The widespread accessibility of ICT worldwide prompts discussions on creating sustainable, resource-efficient, and resilient smart cities, tailored to the needs of different cities, countries, and continents. Each city within a particular country and continent may face unique challenges in achieving smart city economic development. These questions are explored in the book chapter by Kumar and Dahiya (2016): As traditional rural economies transition to urban economies, which contribute significantly to national GDP, the key question arises: what defines smart city economic development? How does it differ from conventional urban economies? Are the theories and practices of conventional urban economies applicable to smart city economies, or is there a need to develop new theories and practices specific to smart city economic development? What role does a "food shed" play in the economy of smart cities? What does industry look like in a smart city context? How do commerce services, transportation, and communication systems impact the smart city economy? How do smart cities integrate into global, regional, and national urban dynamics and policy discussions? Can smart cities and smart economies promote social inclusivity? How can social inclusion be strategically incorporated into smart city development? What forms of governance and institutional support are necessary for smart cities to fulfill their role in the smart economy? What constitutes a sustainable model for economic development in smart cities, and what standards should smart cities adhere to?

Considerable academic interest and consistent funding from national and supranational bodies have focused on how Smart City policies attract relevant financial support. However, there is currently no empirical evidence available regarding the economic rationale behind these policies. Specifically, while a few studies examine the impact of smart urban characteristics and policies on urban performance, no research to date has explored the direct link between these features and policies and their influence on urban performance. Caragliu and Del Bo (2018) address this gap by empirically investigating whether smart urban policies promote urban economic growth. They proceed under the assumption that while smart urban characteristics contribute to long-term growth, their impact on urban performance is indirect. This assumption is tested using an Instrumental Variables approach, where urban performance is analyzed in relation to smart urban policies and a set of control variables. The study utilizes a database encompassing 309 European metropolitan areas, specifically compiled for this analysis and containing data on both smart urban characteristics and the intensity of smart policies. Their empirical findings suggest that higher intensity of Smart City policies correlates with improved urban economic performance. Moreover, by instrumenting smart policies with smart urban characteristics, the study suggests that the causality flows from policy intensity to economic growth, ruling out reverse causality. The study concludes with policy recommendations based on these findings.

While the Cities in Motion Index provides valuable insights into various dimensions of urban development, including governance, urban planning, technology, and sustainability, there is a notable absence of detailed examination focusing specifically on the economic determinants of smart and sustainable urban development. The index typically offers a broad overview and comparative analysis of cities based on qualitative and quantitative indicators. However, it often lacks in-depth exploration into the specific economic drivers and policies that contribute to the success or challenges faced by cities in achieving smart and sustainable urban development goals.

Further research is needed to delve deeper into how economic factors of smart and sustainable cities influenced by their ability of to adopt and sustain smart initiatives while fostering sustainable growth. These studies would help identify interplay of economic variable with other dimensions of urban development, and their overall influence on the trajectory of cities towards becoming smarter and more sustainable. Moreover, comparative analyses across cities of different sizes, regions, and economic contexts would provide valuable insights into the nuanced relationships between economic determinants and the outcomes measured by indices like the Cities in Motion Index.

METHODOLOGY

IESE Cities in Motion is a research platform launched in 2014 jointly by the Globalization and Strategy Center of the IESE Business School and the IESE Strategy Department in Spain. The initiative brings together a global network of experts in cities, specialized private companies and local governments worldwide (IESE, 2022). It is an annually updated indicator of the world's largest cities. The index is a key tool for assessing the overall well-being of urban areas. All its components-indicators represent rating values (scale from 1 to 180, where rating 1 means the highest value among the rated countries). It integrally evaluates the development of the city in the following areas (in brackets, the corresponding database is indicated, which serves as an information source for the corresponding indicator).

1. Economy:

- Ease of starting a business: Top positions in the ranking are held by cities that have a more favorable regulatory environment for setting up and operating a local business (World Bank);
- Mortgage as a percentage of income is the monthly mortgage cost as a proportion of household income (Numbeo);
- The percentage of opportunity-driven early-stage entrepreneurs divided by the percentage of necessity-driven early-stage entrepreneurs (Global Entrepreneurship Monitor);
- Number of headquarters of publicly traded companies (Globalization and World Cities (GaWC));
- Gross domestic product in millions of USD (Euromonitor);
- Estimated GDP for the next year (Euromonitor);
- Gross domestic product per capita (Euromonitor);
- Purchasing power in buying goods and services in the city based on the average salary (Numbeo);
- Labor productivity calculated as GDP/employed population (Euromonitor);
- Hourly wage in the city (Euromonitor);
- Number of calendar days needed to complete the procedures to legally start a business (World Bank).

2. Environment:

- Carbon dioxide emissions from the use of fossil fuels and the manufacture of cement (World Bank);
- Methane emissions caused by human activities (World Bank);
- Environmental Performance Index (Yale University);
- CO_2 Emission Index (Numbeo);
- Index of pollution (Numbeo);
- Annual mean measure of particles in the air with a diameter of less than 10 pm. (Global Residence Index);
- Annual mean measure of particles in the air with a diameter of less than 2.5 pm. (IQAir)
- Percentage of population with access to water supply (World Bank);
- Renewable water sources per capita (FAO);

- Average amount of municipal solid waste generated annually per person (Waste Management for Everyone);
- Risk to the city due to climate change (National Geographic).

3. Governance:

- Bitcoin legal: Whether or not Bitcoin is legal in the city (Nomad List);
- Whether or not the city has ISO 37120 certification to improving urban services and quality of life. The highest value is assigned to the cities that have been certified for the longest time (World Council on City Data (WCCD))
- Number of government buildings and premises in a city (OpenStreetMap);
- Number of embassies in a city (OpenStreetMap);
- Percentage of employed population working in public administration (public sector, defense; education, health, community, social and personal service activities) (Euromonitor);
- E-Participation Index (this index supplements the EGDI and focuses on the use of online services to facilitate provision of information by governments to citizens (“e-information sharing”), interaction with stakeholders (“e-consultation”), and engagement in decision-making processes (“e-decision-making”) (United Nations);
- Human Capital Index (component of IEGDI, which reflects the state of human capacity component) (United Nations);
- Strength of Legal Rights Index (this index measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders and thus facilitate access to loans) (World Bank);
- Index of telecommunication infrastructure (component of IEGDI, which reflects the state of development of telecommunication infrastructure) (United Nations);
- Corruption Perceptions Index (Transparency International);
- Online Service Index (component of IEGDI, which reflects the scope and quality of e-government services) (United Nations);
- Number of research and technology offices in a city (OpenStreetMap);
- Whether or not the city has an open data system (CTIC Foundation and Open World Bank);
- Democracy Index (Economist Intelligence Unit);
- Total reserves. City-level estimate according to population (World Bank);
- Reserves per capita (World Bank).

4. Human capital:

- Proportion of population with secondary and higher education (Euromonitor);
- Number of public and private schools in a city (OpenStreetMap);
- Number of business schools in the city included in the Financial Times TOP 100 (Financial Times);
- Annual private expenditure on education per capita (Euromonitor);
- Consumer expenditure on leisure and recreation as a percentage of GDP (Euromonitor);
- Annual consumer expenditure on leisure and recreation per capita (Euromonitor);
- International flow of mobile students at the tertiary level. Number of students (UNESCO);
- Number of museums and art galleries in a city (OpenStreetMap);
- Number of TOP 500 universities (OS Top Universities);
- Number of theaters in a city (OpenStreetMap).

5. International profile:

- Annual number of passengers per airport (Euromonitor);
- Number of hotels per capita (OpenStreetMap);
- The Restaurant Price Index (compares the price of meals and drinks in restaurants and bars in a city to prices in New York City) (Numbeo);
- Number of McDonald’s establishments in a city (OpenStreetMap);

- Number of international congresses and meetings held in a city (International Congress and Convention Association).

6. ***Mobility and transportation:***

- Whether or not the city has a bicycle rental system (NUMO);
- Whether or not the city has a moped rental system (NUMO);
- Whether or not the city has a scooter rental system (NUMO);
- Percentage of bicycles per household (Euromonitor);
- Automated services for public use of shared bicycles (indicator values according to how developed the system is) (Bike-Sharing WorldMap);
- Number of metro stations in a city (Metrobits);
- Traffic Inefficiency Index (high driving inefficiencies, such as long travel times) (Numbeo);
- Traffic Commute Time Index (based on the time it takes to commute to work) (Numbeo);
- Exponential Traffic Index (estimated by considering time spent in traffic) (Numbeo);
- Length of the metro system in a city (Metrobits);
- Binary variable that shows whether the city has a high-speed train or not (OpenRailwayMap);
- Number of commercial vehicles in a city (Euromonitor);
- Number of inbound flights (air routes) in a city (OpenFlights).

7. ***Social cohesion:***

- Female-friendly (whether a city provides a friendly environment for women) (Nomad List);
- Number of public and private hospitals in a city. Includes health centers (OpenStreetMap);
- Estimation of the general level of crime in a city (Numbeo);
- Slavery Index (the national government's response to situations of slavery in the country) (Walk Free Foundation);
- Happiness Index (World Happiness Index);
- Gini Index (Euromonitor);
- Global Peace Index (the level of peace/violence in a country or region) (Centre for Peace and Conflict Studies, University of Sydney);
- Health Care Index (overall quality of the health care system, health care professionals, equipment, personnel, costs, etc) (Numbeo);
- Whether a city provides a friendly environment for the LGBT community (Nomad List);
- Property price as a proportion of average annual disposable household income (Numbeo);
- Rate of female employment in the public sector (International Labor Organization);
- Death rate per 100,000 city inhabitants (Euromonitor);
- Unemployment rate (unemployed/labor force) (Euromonitor);
- Murder rate per 100,000 city inhabitants (Nomad List);
- Suicide rate per 100,000 city inhabitants (Nomad List);
- Number of terrorist incidents in a city in the last three years (Global Terrorism Database, University of Maryland);
- Index of racial tolerance in a city (Nomad List).

8. ***Technology:***

- Active mobile broadband subscriptions (International Telecommunication Union);
- Innovation Cities Index (2thinknow);
- Percentage of households with Internet access (Euromonitor);
- Percentage of the population covered by at least an LTE/WiMAX mobile network (Euromonitor);
- Percentage of households with a personal computer (Euromonitor);
- Number of mobile phones per 100 inhabitants (International Telecommunication Union);
- Registered Twitter users and LinkedIn members in a city (Twitter and LinkedIn);
- Broadband subscriptions per 100 inhabitants (International Telecommunication Union);

- Percentage of households with some kind of telephone service (Euromonitor);
- Fixed-line Internet speed in megabytes per second (country) (World Population Review);
- Mobile speed in megabytes per second (country) (World Population Review);
- Total number of WiFi hotspots Internet in a city (WiFi Mapapp).

9. Urban planning:

- Whether or not a city has a bike sharing system (The Bike Share Map);
- The number of completed buildings in a city (includes structures such as high-rises, towers and low-rise buildings, but excludes other miscellaneous structures and buildings of different statuses (under construction, proposed, etc.) (Skyscraper Source Media);
- Bicycle station locations in a city (Bike-Sharing World Map);
- Electric car charging points in a city (OpenStreetMap);
- Average number of people per household (Euromonitor);
- Percentage of the urban population that uses at least basic sanitation services – that is, improved sanitation facilities that are not shared with other households (World Bank);
- Whether or not a city has Al projects (Al Localism);
- Percentage of buildings classified as high-rises (at least 12 stories or 35 m in height) (Skyscraper Source Media).

Appendix A presents data on the ranking of 180 world cities in this Index for 2022 (both rankings by the integral value of the Cities in Motion Index (CIMI) and rankings by its individual components).

The purpose of this article is to find out which components of sustainable and smart development of urban areas are the most important for the economy of the city using regression, cluster, and discriminant analysis of the ranking positions of 180 cities of the world according to the Cities in Motion Index (CIMI) and its components in 2022.

The research is conducted in the following sequence:

1. At the first stage, descriptive statistics of the characteristic space of indicators, which are components of the Cities in Motion Index (CIMI), is formed. The purpose of descriptive statistics is to obtain statistical indicators by summarizing the characteristics of the observed population, providing a concise and concentrated description of the studied phenomenon. The Statgraphics 19 program is used for this study.
2. In the second stage, the density of connections between the input parameters of the study is determined using the Spearman and Kendall correlation matrix. Kendall's correlation coefficient is more meaningful; it analyzes the relationships between indicators more fully and in detail, going through all possible correspondences. It is considered more sensitive and robust to outliers because it is calculated based on rank orders without considering specific data values. Spearman's coefficient more accurately considers specifically the quantitative degree of connection between indicators.
3. In the third stage, the normality of the distribution is checked. This study uses the Shapiro-Wilk test and Stata software for this.
4. At the fourth stage, a regression model is developed that describes the influence of all components of the Cities in Motion Index (CIMI) and its integral value on its first component – Economy. This study was done in Stata using the least squares method.
5. At the fifth stage, multicollinearity is checked in independent variables. This study used the VIF test in Stata software for this purpose.
6. At the sixth stage, multiple regression is formed using the challenging screening procedure in the Statgraphics program.
7. At the seventh stage, a variance analysis was conducted to study in more detail the statistical significance of the influence of independent variables on the dependent variable.
8. At the eighth stage, a cluster analysis was conducted to study in more depth the determinants of the formation of the economy of smart and sustainable cities. For this purpose, this study used the Statgraphics program and the k-means method in the R Studio software environment. Each cluster's initial representatives are their centroids, their centers of gravity. K-means randomly selects k data

points as initial centroids. Each data point M is assigned to the cluster with the closest centroid based on the Euclidean distance metric. At the same time, the k-means method minimizes the variance within the cluster, thereby grouping the data points in the cluster that are as similar as possible. It should be noted that this method is sensitive to emissions. The number of clusters was calculated according to the Sturgess formula, the optimality of which was confirmed by the agglomeration scheme according to Ward's method.

9. At the ninth stage of the research, a discriminant analysis was conducted to identify the influence of smart city indicators on clustering results. Discriminant analysis was performed in the Statgraphics program using the Discriminant Analysis procedure.

RESULTS

As already mentioned above, at the first stage of the research, descriptive statistics of the characteristic space of indicators, which are components of the Cities in Motion Index (CIMI), are formed. Table 1 contains the results of such an analysis performed in the Statgraphics 19 program.

Table 1. Descriptive Statistics of the Feature Space of the Cities In Motion Index (CIMI) Components in 180 Cities of the World for 2022

	Economy	Cities in motion	Human capital	Social cohesion	Enviroment	Governance	Urban planning	International profile	Tehnology	Mobility and transportation
Count	180	180	180	180	180	180	180	180	180	180
Average	91.5611	91.4722	92.2444	91.05	89.6889	92.2	91.15	91.9611	91.7278	92.0222
Standard deviation	53.2375	53.1985	53.2367	52.872	52.1064	53.132	52.7623	52.8182	53.2974	53.337
Coeff. of variation	58.14%	58.16%	57.71%	58.07%	58.10%	57.63%	57.89%	57.44%	58.10%	57.96%
Minimum	1	1	1	1	1	1	1	1	1	1
Maximum	183	183	183	183	181	183	182	183	183	183
Range	182	182	182	182	180	182	181	182	182	182
Stnd. skewness	0.107589	0.126928	-0.0549216	0.168276	0.279873	0.00275143	0.0562864	-0.0658214	0.0688081	-0.00178811
Stnd. kurtosis	-3031495	-3.30427	-3.3142	-3.24065	-3.20603	-3.30859	-3.2933	-3.2771	-3.33181	-3.343

Source: calculated by the authors based on data on the ranking of 180 world cities in the Cities in Motion Index for 2022 in the Statgraphics 19 program.

As shown in Table 1, the characteristic space is statically significant according to the criteria of descriptive statistics. However, for all indicators that potentially characterize the economy of smart cities, the kurtosis coefficient exceeds [-2;2]. Statgraphics suggests that the law is different from normal. However, these values vary from -3 to 3, which indicates an insignificant deviation from the normal distribution law. Analyzing the descriptive statistics of the indicators, it can be seen that all indicators consist of 180 observations. The average values of all indicators range from 89.6889 (Environment indicator) to 92.2444 (Human capital indicator), which indicates the similarity of the levels of these indicators. Standard deviations for all indicators are almost the same and range from 52.1 (Environment indicator) and 53.337 (Mobility and transportation indicator), which indicates similar data variability. The coefficients of variation for all indicators are approximately 58%. All indicators have a minimum value of 1. The maximum values of all indicators are 183, except Environment (180) and Urban Planning (181). Most indicators have a slight positive asymmetry, with the exception of Human capital (-0.055), International profile (-0.066) and Mobility and transportation (-0.0018), which have negative or almost zero asymmetry. All indicators have a negative kurtosis, so it is possible to claim a flat distribution. The most negative excess is present in the Mobility and transportation indicator (-3.343), the smallest in Environment (-3.206).

Therefore, after analyzing the descriptive statistics of the input data, it can be stated that all indicators are statistically significant, the coefficients of variation are more than 5%, and the standardized indicators of asymmetry and kurtosis indicate small deviations from the normal distribution law. Standardizing input indicators characterizing the economy of smart cities was not carried out since they are all rating values.

At the second stage, the density of connections between the input parameters of the study is determined using the correlation matrix of Spearman (Figure 1) and Kendall (Figure 2).

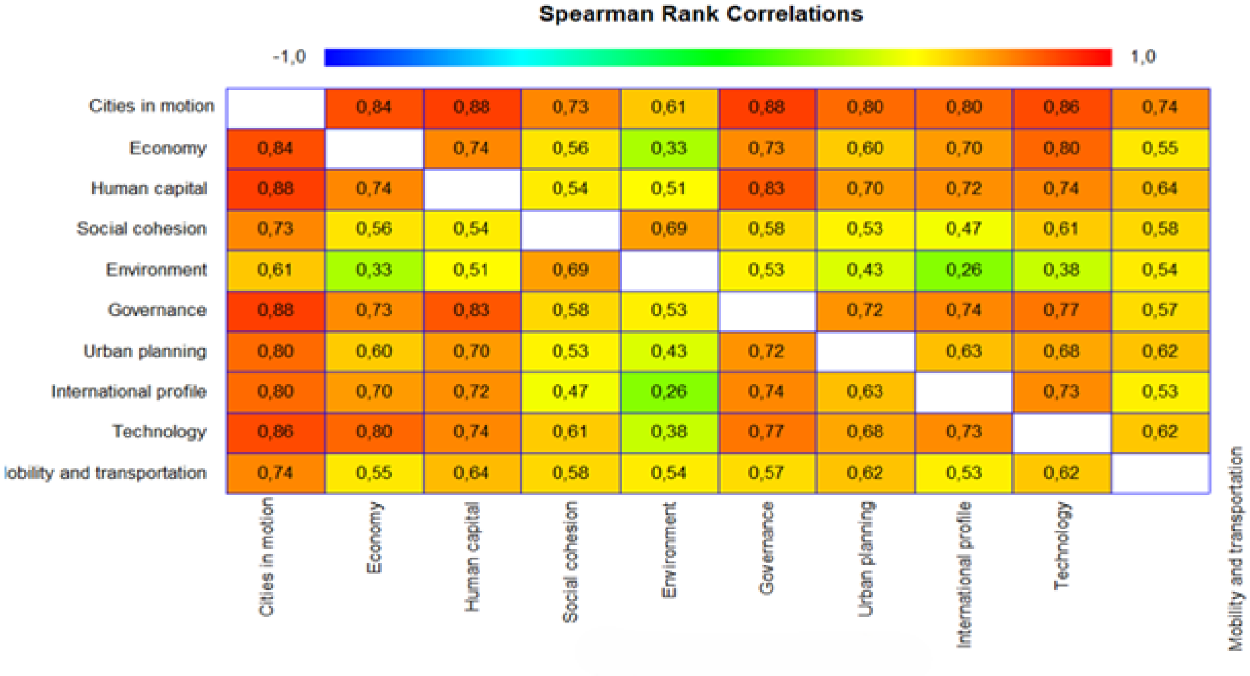

Figure 1. Spearman correlation matrix

Source: created by the authors in Statgraphics.

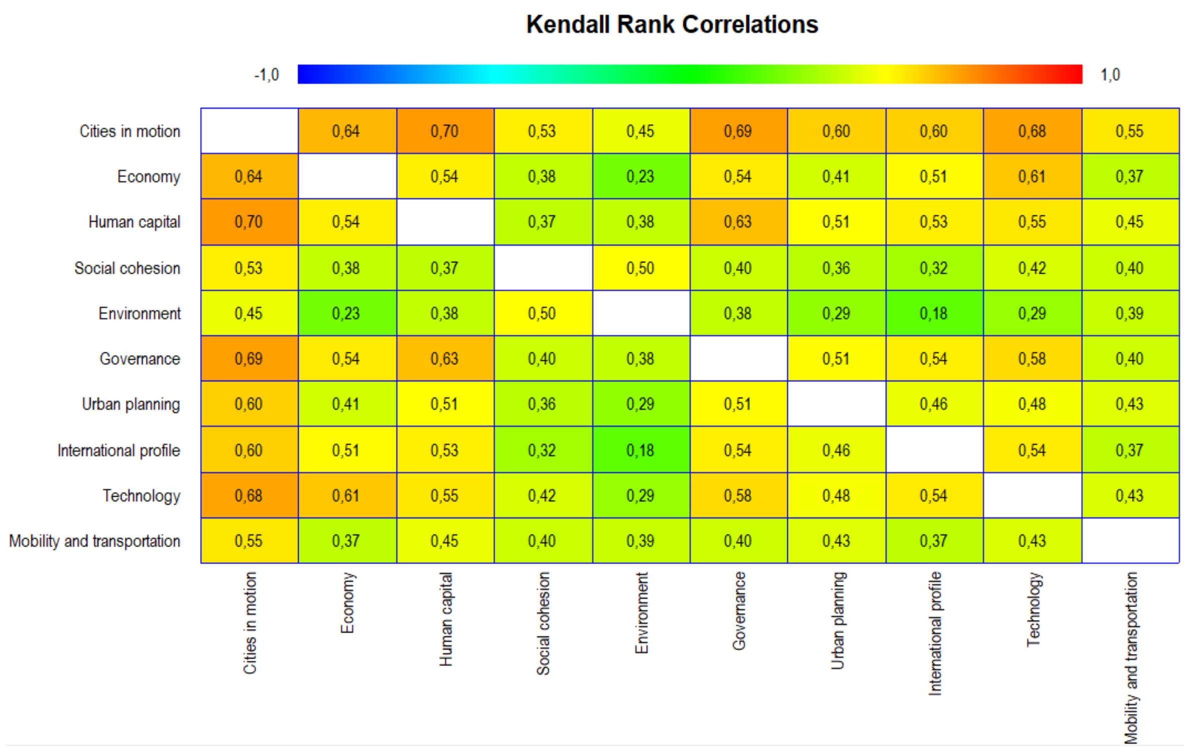

Figure 2. Kendall's correlation matrix

Source: created by the authors in Statgraphics.

Analysis of the Spearman correlation matrix shows a very strong direct relationship between the indicators Economy and Cities in motion (0.84), Human capital and Cities in motion (0.88), Governance and Cities in motion (0.88), Cities in motion and Technology (0.86), Cities in motion and Urban planning (0.8), Cities in motion and International profile (0.8), Technology and Economy (0.8), Human capital and Governance (0.83).

Between the indicators of Social cohesion and Cities in motion (0.73), Cities in motion and Environment (0.61), Mobility and transportation and Cities in motion (0.74), Human capital and Economy (0.74), Governance and Economy (0.73), Urban planning and Economy (0.6), International profile and Economy (0.7), Human capital and Urban planning (0.7), Human capital and International profile (0.72) Human capital and Technology (0.74), Human capital and Mobility and transportation (0.64), Environment and Social cohesion (0.69), Governance and Urban planning (0.72), Governance and International profile (0.74), Governance and Technology (0.77), Urban planning and International profile (0.63), Urban planning and Technology (0.68), Urban planning and Mobility and transportation (0.62), International profile and Technology (0.73), Technology and Mobility and transportation (0.62), a strong direct relationship can be observed.

There is an average direct relationship between the indicators of Economy and Social cohesion (0.56), Economy and Mobility and transportation (0.55), Social cohesion and Human capital (0.54), Human capital and Environment (0.51), Social cohesion and Governance (0.58), Social cohesion and Urban planning (0.53), Social cohesion International profile (0.47), Social cohesion and Technology (0.61), Social cohesion and Mobility and transportation (0. 58), Environment and Urban planning (0.43) Environment and Governance (0.53), Environment and Mobility and transportation (0.54), Governance and Mobility and transportation (0.57), Mobility and transportation and International profile (0.53).

There is a weak direct relationship between the indicators Environment and Economy (0.33), Environment and International profile (0.26), Environment and Technology (0.38).

After analyzing the correlation coefficients of Spearman and Kendall, it can be seen that these coefficients show similar relationships between indicators, so it can be concluded that there is a close relationship between Economy, Human capital, Governance and Cities in motion.

There is a direct relationship between Cities in motion and indicators of Technology, Urban planning, International profile. Average direct relationship exists between Economy, Social cohesion and Mobility and transportation.

At the third stage, the normality of the distribution is checked using the Shapiro-Wilk test in the Stata software. The results of this analysis are shown in Table 2.

Table 2. Shapiro-Wilk Test

Variable	Obs	W	V	z	Prob>z
Economy	180	0.95331	6.357	4.233	0.00001
Cities in motion	180	0.95360	6.317	4.218	0.00001
Human capital	180	0.95336	6.349	4.230	0.00001
Social cohesion	180	0.95570	6.031	4.112	0.00002
Environment	180	0.95650	5.922	4.071	0.00002
Governance	180	0.95382	6.288	4.208	0.00001
Urban planning	180	0.95432	6.219	4.183	0.00001
International profile	180	0.95511	6.112	4.143	0.00002
Technology	180	0.95285	6.420	4.255	0.00001
Mobility and transportation	180	0.95253	6.463	4.271	0.00001

Source: calculated by the authors using Stata.
Notes: Obs. - observations, W – Shapiro-Wilk test, V is the covariance matrix of those normal order statistics, z – z-score, Prob –probability.

According to the statistics of the W indicator, the closer the value is to 1, the better, which characterizes normality. However, the Z indicator is less than 5%, which indicates the non-normality of the distribution.

So, after analyzing the obtained values, we can say that the data distribution of all indicators is similar to normal since the values of the W statistic range from 0.95253 to 0.95650. All p-values are less than 0.05, indicating the presence of outliers.

In the fourth stage, a regression analysis of the relationship between all components of the Cities in Motion Index (CIMI) and its integral value on its first component Economy, was carried out. This study was done in Stata using the least squares method. The obtained results are shown in Table 3.

Table 3. The Influence Of All Components Of The Cities In Motion Index (CIMI) And Its Integral Value On Its First Component Economy

	Coefficient	Std. err.	t	P>|t|	[95% conf. interval]	
					min	max
Cities in motion	0.489112	0.167299	8.90	0.000	1.158861	1.819363
Human capital	-0.0566369	0.0787327	-0.72	0.473	-0.212.565	0.0987828
Social cohesion	-0.0428713	0.0611431	-0.70	0.484	-0.1635689	0.0778263
Environment	-0.3268398	0.0581568	-5.62	0.000	-0.4416423	-0.2120372
Governance	-0.0710056	0.0784066	-0.91	0.366	-0.2257815	0.0837704
Urban planning	-0.2481617	0.0582621	-4.26	0.000	-0.363172	-0.1331513
International profile	-0.1563597	0.0646939	-2.42	0.017	-0.2840665	-0.0286529
Technology	0.1061966	0.0720226	1.47	0.142	-0.0359773	0.2483705
Mobility and transportation	-0.0999986	0.0527843	-1.89	0.060	-0.2041957	0.0041984
cons	36.79709	5.324444	6.91	0.000	26.28654	47.30763

Source: Calculated by the authors using Stata.
Notes: Std. err. – Standard error, t –testing, P - probability.

Analysis of Table 3 shows that almost all indicators have a negative impact on the Economy (except for Cities in motion and Technology). At the same time, only 4 indicators have a statistically significant influence: Cities in Motion, Environment, Urban planning, International profile, and a constant, so these indicators should be left in the model to improve its quality and accuracy.

The adjusted regression model is presented in Table 4.

Table 4. Adjusted Regression Model

Economy	Coefficient	Std. err.	t	P>|t|	[95% conf. interval]	
					min	max
Cities in motion	1.407715	0.0946776	14.87	0.000	1.2208 5 8	1.5 945 72
Environment	-0.3809095	0.0503951	-7.56	0.000	-0.4803699	-0.2814491
Urban planning	-0.2636988	0.057562	-4.58	0.000	-0.377304	-0.1500937
International profile	-0.1569736	0.0642142	-2.44	0.015	-0.2837076	-0.0302397
cons	3 5.42927	4.659326	7.60	0.000	26.23357	44.62498

Source: Calculated by the authors using Stata.
Notes: Coefficient – the estimate is based on standardized indicators, Std. err. – the measure of deviations, t – the statistical value of the indicator for testing the significance hypothesis, P – shows the significance of the indicator.

The study proved the existence of a positive connection between cities in motion and their component, the Economy, which is logical. At the same time, a negative relationship between the Environment indicator and the Economy indicator is proven: a decrease in environmental pollution causes an increase in the city's economic well-being. It should be emphasized the discovery of a negative relationship between the Urban planning indicator and the Economy indicator: smart urban planning involves the allocation of significant areas for bicycle parking, electric car charging stations, bicycle paths, etc., which makes the city more convenient for residents, but limits the urban areas where factories and plants can be located (objects that, in the traditional economic structure, form the city's budget). It would be interesting to investigate this relationship in the long term based on panel data, which would provide a more thorough understanding of the economic background of smart city planning.

The revealed negative relationship between the International profile indicator and the Economy indicator can be explained by the fact that cities that are internationally open and popular for foreign visitors fall into a certain dependence on it because it increases the cost of real estate, mortgages, rents, prices and reduces purchasing power of its residents.

All regression equation coefficients are statistically significant (p-values less than 0.05).

In the fifth stage, multicollinearity is checked in independent variables. In this study, the VIF test was used in Stata software. Table 5 shows the results of this analysis.

Table 5. Multicollinearity Test

Variable	VIF	1/VIF
Cities in motion	7.74	0.129145
International profile	3.51	0.284801
Urban planning	2.82	0.355182
Environment	2.10	0.475129
Mean VIF	4.04	

Source: Calculated by the authors using Stata.
Notes: VIF – variance inflation factor.

Analysis of Table 5 indicates the absence of strong multicollinearity (missing VIF values greater than 10). However, the value of 7.74 for the Cities in motion indicator, although not greater than 10, is still high, which can cause certain problems. Thus, the constructed model can be considered statistically significant and can be used for prediction. The average VIF value is less than 5%, so there is no multicollinearity. The model turned out to be statistically significant. At the next stage, using the hard screening procedure in the Statgraphics program, we obtained the coefficients of the regression relationship presented in Table 6.

Table 6. Regression Table

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	33.5278	4.67591	7.17033	0.0000
Cities in motion	1.41242	0.096994	14.5619	0.0000
Environment	-0.369897	0.0506907	-7.29714	0.0000
Urban planning	-0.25342	0.0580045	-4.36898	0.0000
International profile	-0.146969	0.0647803	-2.26874	0.0245
R-squared =	79.7711			
R-squared (adjusted for d.f.)	79.3087			
R-squared (predicted)	78.731 (PRESS = 107904)			
Standard Error of Est.	24.2165			
Mean absolute error	19.2145			
Durbin-Watson statistic	1.52253 (P=0.0006)			
Lag 1 residual autocorrelation	0.232574			

Source: Calculated by the authors using Stata.
Notes: R-squared – coefficient of determination, Standard Error of Est. – standard error, Mean absolute error – absolute error, Durbin-Watson statistic – Durbin-Watson statistic, Lag 1 residual autocorrelation – residual autocorrelation, P-Value – probability of deviations.

All regression coefficients are statistically significant (p-values less than 0.05).

The analysis of Table 6 confirms the previous conclusions regarding the connection of Environment, Urban planning, International profile, and Cities in motion with the Economy indicator.

The coefficient of determination is 79.3%, indicating the model's high quality. The model has low standard (24.22) and absolute errors (19.21), indicating sufficiently high forecast accuracy. The Durbin-

Watson statistic is 1.52, and the lag 1 of the residual autocorrelation is 0.23, indicating positive autocorrelation in the residuals.

To study in more detail, the statistical significance of the influence of independent variables on the dependent variable, it is necessary to conduct a variance analysis (Table 7).

Table 7. Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	402309,	4	100577,	167.60	0.000
Residual	105020,	175	600,112		
Total (Corr.)	507328,	179			

The results of variance analysis show that the p-Value is less than 0.05, which confirms the statistical significance of the model.

A large value of the F-Ratio indicator (167.6) indicates that the intergroup variation is statistically significant. The sum of squares of the model (402309) exceeds the sum of the residual variation, meaning that the model explains a significant portion of the variation in the data. Based on the obtained results, it is possible to make sure that the coefficients of the regression equation can be used to forecast the variable Economy.

Comparing the results in the Statgraphics program, obtained using the procedure of strict screening of non-significant indicators, it can be concluded that the model is also statistically significant. For a more in-depth analysis of the determinants of the formation of the economy of smart and sustainable cities, a cluster analysis was conducted.

In this study, the Statgraphics program and the k-means method in the R Studio software environment were used for this purpose. It should be noted that the k-means method is sensitive to outliers.

Descriptive analysis of research indicators using Statgraphics software showed their absence (Figure 3).

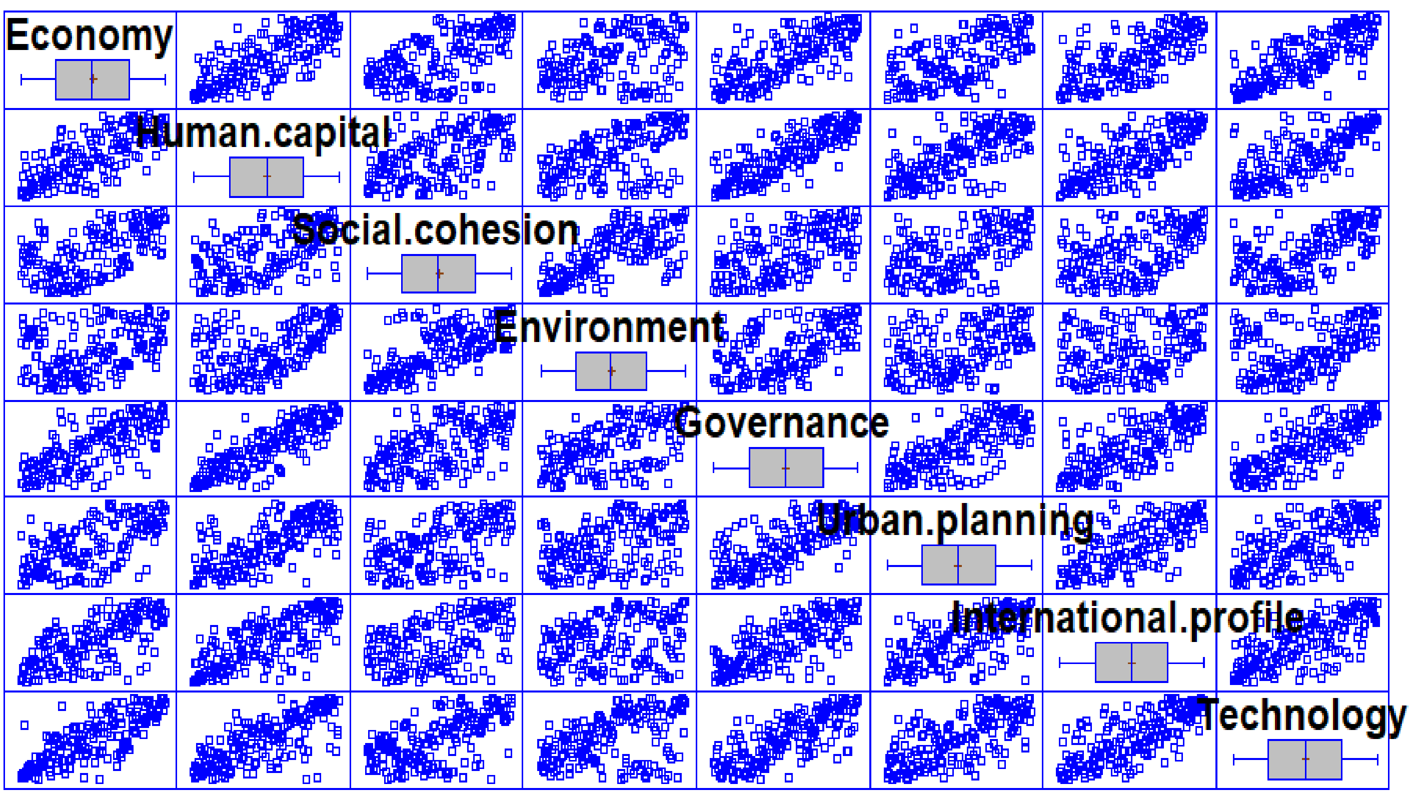

Figure 3. Box and Wisker Plots for Indicators of Cities in Motion

To select the optimal number of clusters, we used the Sturges' rule:

$$k = 1 + 3.332 \lg n, \quad (1)$$

The dplyr library (for filtering, selecting, changing, summarizing and organizing data), ggfortify, ggplot (for visualizing multidimensional data) was used for the analysis. A fragment of the code for dividing cities into clusters is presented in Figure 4.

```
set.seed(21)
kmean <- kmeans(data, 7)
autoplot(kmean, data, frame = TRUE)
data$cluster_id7 <- factor(kmean$cluster)
autoplot(kmean, data, frame = TRUE)+
geom_point(alpha = 1.25,size = 2)+
geom_text(aes(color = cluster_id7, label = rownames(data)))
```

Figure 4. Code Fragment for Dividing Cities into Clusters

Source: written by the authors.

In order to identify patterns in the data and classify cities according to their main social and economic characteristics, a cluster analysis in Statgraphics software is required. As a result of the cluster analysis, 180 cities were divided into 8 clusters (Table 8).

Table 8. Results of Cluster Analysis

Clusters	Members	Percent
1	17	9.44
2	23	12.78
3	35	19.44
4	9	5.00
5	6	3.33
6	33	18.33
7	10	5.56
8	47	26.11

The results of the cluster analysis are presented in Figure 5.

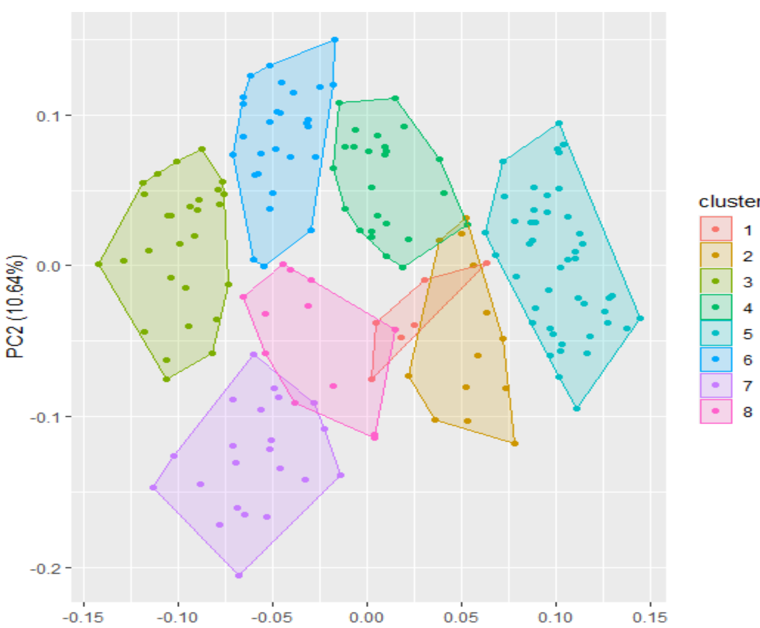

Figure 5. Results of Cluster Analysis using the k-Means Method

Source: calculated by the authors using RStudio.

A more detailed distribution of cities by clusters is presented in Appendix B.

The first cluster included 17 cities (9.44% of the total analyzed population), including London, Paris, Tokyo, Berlin, Singapore, Oslo, Madrid, Barcelona, Vienna, Amsterdam, and others. These are the cities with a high level of economic development, developed infrastructure, and significant cultural and social backgrounds.

The second cluster included 23 cities (12.78% of all analyzed objects), including New York, Washington, Chicago, Toronto, Beijing, Austin, Dallas, Shanghai, Denver, Hong Kong, and others. Large cities from the USA and China dominate this cluster.

The third cluster included 35 cities (which is 19.44% of all analyzed objects), including Hamburg, Basel, Ottawa, Birmingham, Beijing, Montreal, Gothenburg, Liverpool, Leeds, Tallinn, etc. The vast majority of cities in this cluster are significant centers of regional development.

The fourth cluster included 9 cities (5% of all analyzed objects), including Milan, Warsaw, Rome, Brussels, Budapest, Santiago, Buenos Aires, Mexico City and Istanbul. All the cities of this cluster have significant economic and cultural potential.

The fifth cluster had 6 cities (which is 3.33% of all analyzed objects), including Shenzhen, Tianjin, Abu Dhabi, Doha, Guangzhou and Dubai. This cluster contained cities with a well-developed tourism sector, due to which they have rapid economic development.

The sixth cluster included 33 cities (18.33% of all analyzed objects), with Kyiv, Bilbao, Turin, Riga, Lille, Marseille, Nice, Seville, Bratislava, Tel Aviv, and others. In this cluster, almost all cities are European with a developed cultural and historical heritage.

The seventh cluster included 10 cities (5.56% of all analyzed objects), with Belgrade, Cape Town, Bangkok, Panama, Sao Paulo, Naples, Bogotá, Kuala Lumpur, Rio de Janeiro, and Ho Chi Minh City. This cluster consisted of cities with diverse economic and cultural potential.

The eighth cluster included 47 cities (26.11% of all analyzed objects), with Quito, La Paz, San Salvador, Tunis, Brasilia, Santa Cruz, Mumbai, Johannesburg, and Nairobi. This cluster included cities at the development stage, but their opportunities are limited due to weak economic development.

To investigate the statistical significance and strength of influence of individual components of the Cities in Motion Index (CIMI) and its integral value on its first component (Economy variable) for each cluster, it is necessary to construct a multiple regression for each cluster. Building a model with statistically significant variables in the Statgraphics program for the first cluster showed that the following variables remained in the regression equation: constant, Cities in Motion, Mobility and Transportation (Table 9).

Table 9. Statistically Significant Coefficients Of The Regression Equation For The Cluster 1

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	27.9865	8.41349	3.32639	0.0050
Cities in motion	2.6216	0.541356	4.84265	0.0003
Mobility and transportation	-0.58893	0.165304	-3.5627	0.0031
R-squared	63.5476			
R-squared (adjusted for d.f)	58.3401			
R-squared (predicted)	51.8401 (PRESS = 7888.15)			
Standard Error of Est.	20.6511			
Mean absolute error	13.7099			
Durbin-Watson statistic	1.64261 (P=0.1315)			
Lag 1 residual autocorrelation	0.139485			

Source: calculated by the authors in the Statgraphics program.

Notes: R-squared – coefficient of determination, Standard Error of Est. - standard error, Mean absolute error - absolute error, Durbin-Watson statistic - Durbin-Watson statistic, Lag 1 residual autocorrelation - residual autocorrelation, P-Value - probability of deviations.

Therefore, the Cities in motion variable will have the greatest impact on the economy of the cities in the first cluster. The Mobility and Transportation variable also has a minor influence on the dependent variable. Statistically significant p-values (less than 0.05) confirm the influence of these variables on the urban economy. It can be concluded that the regression equation for the first cluster has a relatively high quality (the coefficient of determination is 63.55%). The built model has a low standard error (20.65), which indicates an acceptable accuracy of predictions. The Durbin-Watson statistic is 1.64 and the lag 1 residual autocorrelation is 0.14, indicating no autocorrelations in the model residuals. For the economic development of the cities of the second cluster, the Technology component turned out to be the most significant factor (Table 10).

Table 10. Statistically Significant Coefficients Of The Regression Equation For Cluster 2

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	4.59049	3.05064	1.50476	0.1473
Technology	0.59383	0.10764	5.5168	0.0000
R-squared	59.1718			
R-squared (adjusted for d.f.)	57.2276			
R-squared (predicted)	48.6763 (PRESS =1656.95)			
Standard Error of Est	7.92257			
Mean absolute error	6.18309			
Durbin-Watson statistic	2.89995 (P=0.9906)			
Lag 1 residual autocorrelation	-0.48496			

Source: calculated by the authors in the Statgraphics program.
Notes: R-squared – coefficient of determination, Standard Error of Est. - standard error, Mean absolute error - absolute error, Durbin-Watson statistic - Durbin-Watson statistic, Lag 1 residual autocorrelation - residual autocorrelation, P-Value - probability of deviations.

For the economic development of the cities of the third cluster, the following components turned out to be the most significant factors: Cities in motion, International profile, Mobility and transportation, Social cohesion, Urban planning (Table 11).

Table 11. Statistically Significant Coefficients of the Regression Equation for Cluster 3

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	82.9302	15.6365	5.30363	0.0000
Cities in motion	1.49416	0.23863	6.26142	0.0000
International profile	-0.430783	0.154332	-2.79127	0.5092
Mobility and transportation	-0.514749	0.118856	-4.33086	0.0002
Social cohesion	-0.481639	0.204453	-2.35574	0.0255
Urban planning	-0.241976	0.0988384	-2.4482	0.0206
R-squared	62.2002			
R-squared (adjusted for d.f.)	55.683			
R-squared (predicted)	44.6123(PRESS = 15140.1)			
Standard Error of Est	18.8757			
Mean absolute error	13.9174			
Durbin-Watson statistic	2.08188 (P=0.5288)			
Lag 1 residual autocorrelation	-0.0925779			

Source: calculated by the authors in the Statgraphics program.
Notes: R-squared – coefficient of determination, Standard Error of Est. - standard error, Mean absolute error - absolute error, Durbin-Watson statistic - Durbin-Watson statistic, Lag 1 residual autocorrelation - residual autocorrelation, P-Value - probability of deviations,.

For clusters 4 and 5, the regressions were not significant, therefore, for the analysis of their economy, the indicators should be examined separately by city. For the economic development of the cities of the sixth cluster, the most significant factors were the components: Cities In motion, Environment, Governance, Mobility and transportation, Social cohesion, Urban planning (Table 12).

Table 12. Statistically Significant Coefficients of the Regression Equation for Cluster 6

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	-77.6608	20.8742	-3.72042	0.0010
Cities In motion	3.64175	0.291265	12.5032	0.0000
Environment	-0.632858	0.142894	-4.42885	0.0002
Governance	-0.246269	0.116625	-2.11162	0.0445
Mobility and transportation	-0.591203	0.0890578	-6.63842	0.0000
Social cohesion	-0.299078	0.0987418	-3.02889	0.0055

Table 12 (cont.). Statistically Significant Coefficients of the Regression Equation for Cluster 6

Parameter	Estimate	Standard Error	T Statistic	P-Value
Urban planning	-0.526209	0.0849531	-6.19411	0.0000
R-squared	87.7019			
R-squared (adjusted for d.f.)	84.8639			
R-squared (predicted)	81.9299(PRESS = 7170.59)			
Standard Error of Est	13.7003			
Mean absolute error	9.25957			
Durbin-Watson statistic	1.97747 (P=0.4040)			
Lag 1 residual autocorrelation	-0.00965355			

Source: calculated by the authors in the Statgraphics program.
Notes: R-squared – coefficient of determination, Standard Error of Est. - standard error, Mean absolute error - absolute error, Durbin-Watson statistic - Durbin-Watson statistic, Lag 1 residual autocorrelation - residual autocorrelation, P-Value - probability of deviations.

For the economic development of the cities of the seventh cluster, the following components turned out to be the most significant factors: Human capital, Social cohesion, Technology (Table 13).

Table 13. Statistically Significant Coefficients of The Regression Equation for Cluster 7

Parameter	Estimate
CONSTANT	-160.644
Human capital	2.95245
Social cohesion	1.49265
Technology	-2.15088
R-squared	93.0489
R-squared (adjusted for d.f.)	89.5734
R-squared (predicted)	59.9912 (PRESS = 5675.85)
Standard Error of Est	12.82
Mean absolute error	8.45876
Durbin-Watson statistic	1.65691 (P=0.3054)
Lag 1 residual autocorrelation	0.0206474

Source: calculated by the authors in the Statgraphics program.
Notes: R-squared – coefficient of determination, Standard Error of Est. - standard error, Mean absolute error - absolute error, Durbin-Watson statistic - Durbin-Watson statistic, Lag 1 residual autocorrelation - residual autocorrelation, P-Value - probability of deviations.

For the economic development of the cities of the eighth cluster, the components: Cities in motion, Environment, Technology, Urban planning turned out to be the most significant factor (Table 14).

Table 14. Statistically Significant Coefficients of The Regression Equation for Cluster 8

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	29.7541	28.7986	1.03318	0.3074
Cities in motion	1.8153	0.246904	7.35225	0.0000
Environment	-0.57671	0.102211	-5.64235	0.0000
Technology	-0.276402	0.127617	-2.16587	0.0360
Urban planning	-0.312649	0.10777	-2.90107	0.0059
R-squared	58.8938			
R-squared (adjusted for d.f.)	54.979			
R-squared (predicted)	48.7769 (PRESS = 13814.7)			
Standard Error of Est	16.2468			
Mean absolute error	12.6783			
Durbin-Watson statistic	1.88839 (P=0.3013)			
Lag 1 residual autocorrelation	0.0166593			

Source: calculated by the authors in the Statgraphics program.
Notes: R-squared – coefficient of determination, Standard Error of Est. – standard error, Mean absolute error – absolute error, Durbin-Watson statistic – Durbin-Watson statistic, Lag 1 residual autocorrelation – residual autocorrelation, P-Value – probability of deviations.

At the next stage of the research, a discriminant analysis was conducted. In this case, differences are needed to discriminate objects based on certain characteristics and to detect the influence of smart city indicators on clustering results. Discriminant analysis was performed in the Statgraphics program using the Discriminant Analysis procedure (Table 15).

Table 15. Results of Discriminant Analysis

Discriminant Function	Eigenvalue	Relative Percentage	Canonical Correlation
1	13.6431	73.92	0.96525
2	2.88767	15.65	0.86184
3	0.909682	4.93	0.69018
4	0.584641	3.17	0.60741
5	0.287711	1.56	0.47268
6	0.129164	0.70	0.33821
7	0.0143495	0.08	0.11894

Source: calculated by the authors in the Statgraphics program using the Discriminant Analysis procedure.

After analyzing the eigenvalues of each discriminant function, it can conclude that the first two functions are essential since their eigenvalues are more significant than the others. Using the relative percentage, you can determine how much of the total variance each function explains. The first function explains 73.92% of the total variance and the second 15.65, which confirms their significant importance. The highest canonical correlations are present for the first and second functions, which indicates a strong relationship between the discriminant function and the groups. The significance test results of discriminant functions are presented in Table 16.

Table 16. Significance Test of Discriminant Functions

Functions Deriver	Wilks Lambda	Chi-Square	DF	P-Value
1	0.0039357	944.1722	63	0.0000
2	0.0576309	486.5551	48	0.0000
3	0.22405	255.0486	35	0.0000
4	0.427864	144.7459	24	0.0000
5	0.678011	66.2549	15	0.0000
6	0.873082	23.1412	8	0.0032
7	0.985854	2.4292	3	0.4882

Source: calculated by the authors in the Statgraphics program using the Discriminant Analysis procedure.
Notes: Wilks Lambda - value of Wilks's Lambda, Chi-Square - chi-square criterion for evaluating hypotheses, P-Value - probability of deviations.

Analysis of Table 16 showed that the first discriminant function is highly significant as $p<0.0001$ and has the lowest value of Wilks's Lambda, indicating the best group resolution. The value of Wilks' Lambda for each successive feature will increase, indicating a decreasing contribution to group separation for those features. The first five discriminant functions can be considered statistically significant because their values are $p<0.0001$; the sixth function can also be considered statistically significant, but its contribution to group separation is minimal. For the seventh discriminant function, the p-value is 0.4882, so it is not statistically significant.

To investigate which of the indicators had the greatest influence on the distribution of clusters, the sum of the coefficients of all 6 statistically significant functions was taken (Table 17).

Table 17. Influence On The Distribution Of Clusters

	Discriminant functions						Sum
	1	*2*	*3*	*4*	*5*	*6*	
Cities in motion	-0.010965	-0.556695	0.176584	0.895158	0.637271	-0.296871	0.844482
Environment	0.158604	0.967485	0.215326	-0.030071	0.108036	0.496216	1.915596
Governance	0.337766	0.191616	0.211788	-0.059901	-0.42459	-0.56205	-0.30537

Analyzing Table 17, it can be concluded that the Environment indicator most influenced the distribution of clusters into groups; its value is 1.915596.

Thus, based on the discriminant analysis results, further analysis should be carried out based on the first two functions because they provide the central part of the model's explanatory power.

CONCLUSIONS

The goal of the article is to determine which components of sustainable and smart development of urban areas are the most important for the economy of a city. For this, regression, cluster and discriminant analysis were applied, using the data of the ranking positions of 180 cities of the world according to the Cities in Motion Index (CIMI) and its components for 2022.

The study is based on IESE Cities in Motion, a research platform launched in 2014 jointly by the Center for Globalization and Strategy of the IESE Business School and the IESE Strategy Department in Spain, which brings together a global network of experts in cities, specialized private companies and local governments from around the world. It is an annually updated indicator of the world's largest cities and is a key tool for assessing the overall well-being of urban areas. It integrally evaluates the city's development in such directions as Economy, Human capital, Social cohesion, Environment, Governance, Urban planning, International profile, Technology, Mobility and transportation.

Descriptive statistics analysis of the input data performed in the Statgraphics 19 program showed that all indicators are statistically significant, the coefficients of variation are greater than 5%, and the standardized measures of skewness and kurtosis indicate small deviations from the normal distribution law.

The density of relationships between the input parameters of the study is estimated using the Spearman and Kendall correlation matrix. Spearman's correlation matrix analysis shows a solid direct relationship between Economy and Cities in motion (0.84), Human capital and Cities in motion (0.88), Governance and Cities in motion (0.88), Cities in motion and Technology (0.86), Cities in motion and Urban planning (0.8), Cities in motion and International profile (0.8), Technology and Economy (0.8), Human capital and Governance (0.83). The correlation coefficients of Spearman and Kendall prove similar relationships between the indicators: a close relationship between Economy, Human capital, Governance and Cities in motion; direct dependence between Cities in motion and indicators of Technology, Urban planning, International profile; average direct connection between Economy, Social cohesion and Mobility and transportation.

The normality of data distribution is confirmed by the Shapiro-Wilk test in Stata software. A regression analysis of the relationship between all the components of the Cities in Motion Index (CIMI) and its integral value on its first component – Economy is carried out. It is done in Stata using the least squares method. The analysis proves that only 4 indicators have a statistically significant impact: Cities in Motion, Environment, Urban planning, International profile. A regression equation is built, all coefficients of which are statistically significant (p-values less than 0.05). The study proves the existence of a positive connection between Cities in motion and its component Economy, which is logical. At the same time, the presence of a negative relationship between the Environment indicator and the Economy indicator is proven: a decrease in environmental pollution causes an increase in the economic well-being of the city. It should be emphasized the discovery of a negative relationship between the Urban planning indicator and the Economy indicator: smart urban planning involves the allocation of significant areas for bicycle parking, electric car charging stations, bicycle paths, etc., which makes the city more convenient for residents, but limits the urban areas where factories and plants can be located (objects that, in the traditional economic structure, form the city's budget). It would be interesting to investigate this relationship in the long term based on panel data, which would provide a more thorough understanding of the economic background of smart city planning. The revealed negative relationship between the International profile indicator and the Economy indicator is explained by the fact that in cities that are internationally open and popular for foreign visitors, they fall into a certain dependence on it, because it increases the cost of real estate, mortgages, rents, prices and reduces purchasing power of the local residents.

A multiple regression was also constructed using the hard dropout procedure in the Statgraphics program, all coefficients are statistically significant. It confirms the previous conclusions regarding the connection of Environment, Urban planning, International profile and Cities in motion with the Economy indicator. The VIF test in Stata software confirms the absence of strong multicollinearity in the independent variables.

To study in more detail the statistical significance of the influence of independent variables on the dependent variable, a variance analysis is conducted. It testifies that the p-value is less than 0.05, confirming the constructed equation's statistical significance. A significant value of the F-Ratio indicator (167.6) indicates that the intergroup variation is statistically significant. The sum of squares of the model (402309) exceeds the sum of the residual variation, which means that the model explains a significant part of the variation in the data. The results indicate that the regression equation coefficients is used to forecast the Economy variable.

A cluster analysis is conducted to provide a more in-depth analysis of the Economy within clusters. The Statgraphics program using the Ward method and the k-means method in the R Studio software environment was used for this. The number of clusters is calculated according to the Sturgess formula, as a result of which 8 clusters were obtained, and the optimal number of clusters is also confirmed by the agglomeration scheme according to Ward's method. Using cluster analysis, cities are divided into groups according to their main social and economic characteristics.

The first cluster includes 17 cities of the world with a high level of economic development, developed infrastructure, and significant cultural and social background (9.44% of the studied cities). They are London, Paris, Tokyo, Berlin, Singapore, Oslo, Madrid, Barcelona, Vienna, Amsterdam, etc.

The second cluster includes 23 cities (12.78%), and it is dominated by large cities in the USA and China (including New York, Washington, Chicago, Toronto, Beijing, Austin, Dallas, Shanghai, Denver, Hong Kong, etc.).

The third cluster includes 35 cities (19.44% of all analyzed objects), with Hamburg, Basel, Ottawa, Birmingham, Beijing, Montreal, Gothenburg, Liverpool, Leeds, Tallinn, etc. The vast majority of cities in this cluster are significant regional development centres.

The fourth cluster includes 9 cities (5%): Milan, Warsaw, Rome, Brussels, Budapest, Santiago, Buenos Aires, Mexico City, and Istanbul.

The fifth cluster contains 6 cities (3.33%): Shenzhen, Tianjin, Abu Dhabi, Doha, Guangzhou and Dubai.

The sixth cluster includes 33 cities (18.33%), with Kyiv, Bilbao, Turin, Riga, Lille, Marseille, Nice, Seville, Bratislava, and Tel Aviv. European cities dominate with a developed cultural and historical heritage.

The seventh cluster includes 10 cities (5.56%): Belgrade, Cape Town, Bangkok, Panama, Sao Paulo, Naples, Bogotá, Kuala Lumpur, Rio de Janeiro, and Ho Chi Minh City. The eighth cluster has 47 cities (26.11%), including Quito, La Paz, San Salvador, Tunis, Brasilia, Santa Cruz, Mumbai, Johannesburg, and Nairobi. This cluster includes cities that are still developing but face economic obstacles on the way to their development.

Constructed multiple regressions for each cluster proves that for the cities of the first cluster, Cities in motion have the most significant influence on the Economy component, while Mobility and Transportation are less significant; for cities of the second cluster – Technology; for the cities of the third cluster – Cities in motion, International profile, Mobility and transportation, Social cohesion, Urban planning; for clusters 4 and 5, the regressions were not significant (most likely due to the small number of cities in these clusters), so they require further research separately for each city; for the cities of the sixth cluster – Cities In motion, Environment, Governance, Mobility and transportation, Social cohesion, Urban planning; for cities of the seventh cluster – Human capital, Social cohesion, Technology; for the cities of the eighth cluster – Cities in motion, Environment, Technology, Urban planning. A discriminant analysis is conducted. It is performed in the Statgraphics program using the Discriminant Analysis procedure. It testifies that the Environment indicator most influenced the distribution of clusters into groups.

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Conflicts of Interest

Authors declare no conflict of interest.

Data Availability Statement

Not applicable.

Informed Consent Statement

Not applicable.

REFERENCES

1. Addas, A. (2023). The concept of smart cities: a sustainability aspect for future urban development based on different cities. *Frontiers in Environmental Science*, *11*, 1241593. [CrossRef]
2. Ayanda, K. E. (2023). *Driving Smarter Decisions: The Crucial Role of Data in Smart City Performance Management*. [Link]
3. Berrone, P., Ricart, J. E., Duch, A., Carrasco, C. (2019). *IESE Cities in Motion Index 2019*, IESE, ST-509-E, 05/2019. [CrossRef]
4. Cantuarias-Villessuzanne, C., Weigel, R., Blain, J. (2021). Clustering of European Smart Cities to Understand the Cities' Sustainability Strategies. *Sustainability*. *13*(2), 513. [CrossRef].
5. Caraglium, A., Del Bo C. F., Nijkamp, P. (2011). Smart cities in Europe. *J Urban Technol*, *18*(2), 65–82. [CrossRef]
6. Cocoflo. (2023, March 7). *Driving economic growth with smart city innovations.* [Link]
7. CORDIS. (2023, May 12). *Smart cities are safe cities: enhancing security for all.* [Link]
8. Enel X. (2024). *What is Smart City Management?* [Link]
9. Flanders Investment & Trade (FIT). (2023, May). *Smart City Lima*. [Link]
10. Four, C. (2014). *Cities in Motion for ITS and Transport*. [Link]
11. Giffinger, R., Haindlmaier, G., Kramar, H. (2010). The role of rankings in growing city competition. *Urban Research & Practice, 3*(3), 299-312. [CrossRef]
12. Hello Lamp Post. (2023, October 31). *Smart Governance: A Hybrid of Civic Technology IoT and Local Government.* [Link]
13. IESE. (2022). *IESE Cities in Motion Index*. [Link]
14. Johnson, K. (2018, July 19). *Environmental benefits of smart city solutions.* Foresight. [Link]
15. Kenger, Ö. N., Kenger, Z. D., Özceylan, E. and Mrugalska, B. (2023). Clustering of Cities Based on Their Smart Performances: A Comparative Approach of Fuzzy C-Means, K-Means, and K-Medoids, in *IEEE Access*, *11*, 134446-134459. [CrossRef].
16. Kuzior, A., Arefieva, O., Vovk, O., & Brożek, P., (2022). Innovative Development of Circular Systems While Ensuring Economic Security in the Industry. *Journal of Open Innovation: Technology, Market and Complexity, 8*(3), 139. [CrossRef]
17. Kuzior, A., Postrzednik-Lotko, K.A., Smołka-Franke, B. & Sobotka, B. (2023a). Managing Competences of Generation Y and Z in the Opinion of the Management Staff in the Modern Business Services Sector. *Sustainability*, 15, 5741. [CrossRef].
18. Kuzior, A., Sobotka, B., Postrzednik-Lotko, K. A. & Smołka-Franke, B. (2023b). Managing Competences of Generation Y and Z in the Opinion of the Employees in the Modern Business Services Sector in Poland in the Post-Pandemic Period. *Sustainability*, 15, 14925. [CrossRef].
19. Lai, C. M. T., & Cole, A. (2023). Measuring progress of smart cities: Indexing the smart city indices. *Urban governance*, *3*(1), 45-57. [CrossRef]
20. O'Brien, K. (2023, May 23). What is smart transportation? *IBM Blog.* [Link]
21. Pajilani, N. D. B., Fahmy-Abdullah, M., Sufahani, S. F., & Ali, M. K. B. (2022). Smart economy through smart cities. In M. S. Kaiser, K. Ray, A. Bandyopadhyay, K. Jacob, & K. S. Long (Eds.). *Proceedings of the Third International Conference on Trends in Computational and Cognitive Engineering* (Vol. 348: Lecture Notes in Networks and Systems). Springer. [CrossRef]
22. RideAmigos. (2019). *Smart Mobility in the Smart Cities of Tomorrow*. [Link]
23. Seagate. *The Role of Data Storage in Smart City Operations* (2024). [Link]
24. Tarn, D. (2023, October 27). *Top Smart City Software Development Companies.* ReVerb. [Link]
25. Vinod Kumar, T.M., Dahiya, B. (2017). Smart Economy in Smart Cities. In: Vinod Kumar, T. (eds) *Smart Economy in Smart Cities*. Advances in 21st Century Human Settlements. Springer, Singapore. [CrossRef]

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Appendix A. Rating of Cities according to the Cities in Motion Index (CIMI) and its Components

#	City	Cities in motion	Economy	Human capital	Social cohesion	Environment	Governance	Urban planning	International profile	Technology	Mobility and transportation
1	London - United Kingdom	1	7	1	25	17	2	1	1	18	4
2	New York - USA	2	1	3	121	105	10	2	3	6	1
3	Paris - France	3	9	5	67	49	17	34	2	27	3
4	Tokyo - Japan	4	2	10	41	25	9	112	6	9	62
5	Berlin - Germany	5	94	7	40	21	3	5	14	39	7
6	Washington - USA	6	11	4	73	131	8	9	41	7	37
7	Singapore - Singapore	7	20	40	31	78	24	26	4	4	58
8	Amsterdam - Netherlands	8	38	35	48	14	40	13	18	10	20
9	Oslo - Norway	9	25	18	21	2	11	33	37	28	33
10	Copenhagen - Denmark	10	46	45	4	3	20	23	25	22	31
11	Munich – Germany	11	62	39	8	18	48	8	42	42	11
12	Seoul - South Korea	12	21	8	68	76	6	22	19	25	41
13	Chicago - USA	13	10	13	103	118	34	25	10	13	56
14	Zurich - Switzerland	14	17	25	13	22	16	69	31	23	49
15	Vienna - Austria	15	77	34	83	11	22	11	20	87	8
16	San Francisco - USA	16	5	28	101	132	46	14	33	5	121
17	Hamburg - Germany	17	83	12	43	29	37	6	58	57	13
18	Dublin - Ireland	18	6	93	49	42	70	56	29	121	65
19	Rotterdam - Netherlands	19	56	76	39	38	42	4	90	14	28
20	Helsinki - Finland	20	41	63	10	7	21	20	46	49	42
21	Toronto - Canada	21	48	36	55	65	36	3	23	47	113
22	Los Angeles - USA	22	4	6	72	161	12	36	11	8	179
23	Seattle - USA	23	8	68	82	102	32	17	49	12	81
24	Boston - USA	24	12	2	78	120	15	59	43	29	109
25	Stockholm - Sweden	25	37	47	60	6	30	80	39	16	19
26	Hong Kong - China	26	24	23	158	101	27	27	7	1	69
27	Madrid - Spain	27	80	51	36	68	25	46	17	40	6
28	Bern – Switzerland	28	39	79	6	26	1	70	73	37	34
29	Basel - Switzerland	29	19	91	20	28	5	92	45	51	53
30	Houston - USA	30	3	46	93	148	49	30	32	11	138
31	Barcelona – Spain	31	109	33	71	67	28	15	24	48	10
32	Manchester - United Kingdom	32	34	31	37	39	69	28	66	61	43
33	Reykjavik - Iceland	33	79	85	19	1	87	135	60	80	64
34	Taipei - Taiwan	34	69	15	1	80	4	52	67	68	27
35	Edinburgh - United Kingdom	35	42	11	2	10	62	106	47	62	103
36	Sydney - Australia	36	52	19	11	52	18	119	13	43	128
37	Beijing - China	37	28	37	66	173	68	32	16	50	2
38	Melbourne - Australia	38	61	16	12	70	13	82	15	44	120
39	Lyon - France	39	32	57	52	53	80	48	111	54	21
40	Canberra - Australia	40	35	9	3	8	29	130	97	71	83
41	Frankfurt - Germany	41	71	41	54	27	64	57	56	55	18
42	Miami - USA	42	22	14	110	152	51	49	21	17	54
43	Prague - Czech Republic	43	121	32	45	15	65	41	35	30	29
44	Cologne – Germany	44	95	22	29	51	58	37	82	63	17
45	Montreal - Canada	45	72	50	32	50	83	10	40	73	117
46	Dallas - USA	46	13	21	90	121	53	146	38	33	39
47	Geneva – Switzerland	47	27	98	42	55	19	90	44	35	104
48	Stuttgart - Germany	48	75	52	14	16	109	44	105	66	23
49	Eindhoven - Netherlands	49	57	107	9	13	44	50	102	26	59
50	Ottawa - Canada	50	74	55	7	23	33	19	86	103	89
51	Birmingham - United Kingdom	51	33	49	23	30	66	77	104	99	61
52	Austin - USA	52	23	24	76	113	50	40	93	20	55
53	Gothenburg - Sweden	53	54	69	53	4	73	68	77	41	72
54	Denver - USA	54	14	38	99	136	56	60	48	15	70
55	Vancouver - Canada	55	73	96	30	35	93	12	54	75	94
56	Shanghai - China	56	40	29	47	163	121	109	9	53	5
57	Milan - Italy	57	66	20	91	81	91	66	28	90	16
58	San Diego - USA	58	16	30	74	125	14	102	50	21	76

Appendix A (cont.). Rating of Cities according to the Cities in Motion Index (CIMI) and its Components

#	City	Cities in motion	Economy	Human capital	Social cohesion	Environment	Governance	Urban planning	International profile	Technology	Mobility and transportation
59	Auckland - New Zealand	59	60	64	26	32	39	75	61	74	68
60	Philadelphia - USA	60	15	17	107	134	43	43	69	19	119
61	Liverpool - United Kingdom	61	49	58	16	19	74	74	96	78	91
62	Warsaw - Poland	62	105	62	86	72	7	24	64	76	26
63	Dubai - United Arab Emirates	63	100	143	27	156	60	7	12	2	98
64	Düsseldorf – Germany	64	87	72	28	40	85	71	95	67	14
65	Rome - Italy	65	88	66	102	91	26	47	22	102	24
66	Glasgow - United Kingdom	66	64	59	15	20	63	62	71	83	112
67	Brussels - Belgium	67	59	110	112	60	35	61	51	94	15
68	Baltimore - USA	68	26	61	140	108	45	18	87	46	66
69	Leeds - United Kingdom	69	36	53	24	43	72	96	115	91	88
70	Wellington - New Zealand	70	84	26	5	5	38	138	118	60	77
71	Nottingham - United Kingdom	71	55	48	17	31	75	85	114	89	118
72	Tallinn - Estonia	72	82	80	22	9	86	73	98	70	85
73	Antwerp - Belgium	73	76	104	46	64	98	54	83	119	25
74	Detroit - USA	74	29	27	138	143	57	21	88	31	102
75	Santiago - Chile	75	58	75	100	75	71	55	59	109	47
76	Marseille - France	76	43	101	58	69	81	95	110	88	45
77	Quebec - Canada	77	78	88	18	36	52	45	119	96	110
78	Lisbon - Portugal	78	122	125	69	61	84	39	26	56	36
79	Phoenix - USA	79	18	60	95	135	61	94	53	34	114
80	Nagoya - Japan	80	44	105	57	24	112	104	134	36	78
81	San Antonio - USA	81	31	42	124	107	54	58	81	38	107
82	Osaka - Japan	82	63	97	84	37	67	105	74	24	87
83	Nice - France	83	47	102	79	62	92	100	78	92	63
84	Lille - France	84	45	113	56	46	90	84	122	97	84
85	Budapest - Hungary	85	107	43	122	71	77	29	62	116	51
86	Valencia - Spain	86	125	109	50	47	41	65	107	59	32
87	Bratislava - Slovakia	87	128	70	51	33	88	51	131	126	35
88	Linz - Austria	88	102	84	34	12	119	81	113	124	48
89	Las Vegas - USA	89	30	77	143	130	55	53	63	32	130
90	Duisburg - Germany	90	113	81	35	34	107	86	121	98	57
91	Tel Aviv - Israel	91	51	134	33	87	78	87	75	86	127
92	Istanbul - Turkey	92	67	89	136	119	97	76	8	112	122
93	Malaga - Spain	93	134	74	77	59	110	108	125	82	22
94	Riga - Latvia	94	119	65	105	45	158	38	126	128	52
95	Seville - Spain	95	133	99	81	58	104	64	133	100	40
96	Vilnius - Lithuania	96	85	67	141	44	101	63	130	113	93
97	Turin - Italy	97	99	83	109	85	123	78	99	120	38
98	Ljubljana - Slovenia	98	98	95	59	48	116	101	106	114	124
99	Wroclaw - Poland	99	110	73	111	82	94	31	149	106	92
100	Zagreb – Croatia	100	70	78	104	66	59	124	117	115	115
101	Guangzhou - China	101	65	140	63	164	157	103	65	45	12
102	Buenos Aires - Argentina	102	160	56	128	79	31	35	34	131	135
103	Florence – Italy	103	106	82	127	84	125	107	89	107	46
104	Kuala Lumpur - Malaysia	104	68	114	85	142	135	120	36	117	67
105	Palma de Mallorca - Spain	105	135	112	65	59	120	79	100	77	106
106	A Coruña - Spain	106	127	115	80	41	117	83	150	52	95
107	Zaragoza - Spain	107	123	106	70	59	127	154	135	95	30
108	Shenzhen - China	108	50	145	108	158	170	113	79	65	9
109	Bilbao - Spain	109	129	132	75	57	118	88	127	79	73
110	Bucharest - Romania	110	93	100	125	89	124	111	94	93	71
111	Murcia - Spain	111	131	120	64	63	132	89	153	85	96
112	Porto - Portugal	112	137	139	62	56	79	141	109	69	90
113	Abu Dhabi - United Arab Emirates	113	81	156	44	172	96	72	84	3	105
114	Mexico City - Mexico	114	117	54	116	167	82	42	55	148	79
115	Jerusalem - Israel	115	86	144	87	83	113	122	80	123	151
116	Kyiv - Ukraine	116	149	86	173	92	47	16	138	135	108

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Appendix A (cont.). Rating of Cities according to the Cities in Motion Index (CIMI) and its Components

#	City	Cities in motion	Economy	Human capital	Social cohesion	Environment	Governance	Urban planning	International profile	Technology	Mobility and transportation
117	Bangkok – Thailand	117	136	108	113	145	149	174	5	84	125
118	Sofia – Bulgaria	118	146	90	144	86	76	134	136	105	50
119	Panama - Panama	119	53	149	94	104	150	125	85	164	99
120	Athens - Greece	120	101	87	179	94	128	150	52	58	74
121	Naples - Italy	121	118	118	132	88	156	136	108	122	97
122	Ankara - Turkey	122	90	116	133	114	111	131	155	147	75
123	Belgrade - Serbia	123	92	94	145	90	130	165	124	111	140
124	Doha - Qatar	124	104	180	38	159	169	67	92	64	86
125	Montevideo - Uruguay	125	171	128	96	54	100	117	128	132	132
126	Tbilisi - Georgia	126	97	131	146	116	106	157	164	129	82
127	Minsk - Belarus	127	172	92	142	77	89	127	162	138	80
128	Almaty - Kazakhstan	128	103	124	135	129	141	93	167	149	123
129	São Paulo - Brazil	129	151	123	147	126	122	133	27	127	177
130	Bogota - Colombia	130	116	103	174	100	102	181	68	130	149
131	Rosario - Argentina	131	159	130	139	73	136	123	160	141	167
132	Ho Chi Minh City - Vietnam	132	157	138	115	139	148	143	91	125	126
133	Cordoba - Argentina	133	165	142	126	74	139	145	156	144	133
134	Rio de Janeiro - Brazil	134	169	122	175	110	95	97	70	143	157
135	Tianjin - China	135	96	141	88	180	171	156	142	104	44
136	Medellin – Colombia	136	115	146	155	95	138	172	148	146	141
137	Nur Sultan - Kazakhstan	137	148	151	130	111	143	115	158	152	137
138	Baku - Azerbaijan	138	126	133	117	133	168	161	152	140	146
139	Cape Town - South Africa	139	155	119	176	103	137	116	103	137	172
140	Lima - Peru	140	89	126	154	153	153	158	129	166	173
141	Santo Domingo - Dominican Republic	141	120	160	118	127	162	129	163	171	153
142	Kuwait City - Kuwait	142	156	181	97	154	154	110	151	101	152
143	Sarajevo - Bosnia-Herzegovina	143	167	136	159	99	165	149	174	155	100
144	Skopje - Macedonia	144	150	148	149	115	126	173	175	136	129
145	Cali - Colombia	145	112	158	148	97	133	182	180	151	160
146	Delhi - India	146	108	153	169	176	108	144	57	162	131
147	Riyadh - Saudi Arabia	147	132	173	131	160	142	175	145	72	147
148	Manama – Bahrain	148	138	179	61	165	177	99	139	150	155
149	Jakarta - Indonesia	149	154	135	114	162	105	168	72	133	181
150	Curitiba - Brazil	150	173	162	156	93	129	164	171	153	143
151	San Jose - Costa Rica	151	142	165	150	122	99	166	123	139	182
152	Quito - Ecuador	152	178	127	89	128	176	139	144	168	159
153	La Paz - Bolivia	153	153	157	119	98	175	151	179	175	154
154	San Salvador - El Salvador	154	139	159	177	124	160	114	168	161	144
155	Tunis - Tunisia	155	158	166	129	138	152	153	181	163	145
156	Brasilia - Brazil	156	166	168	163	141	115	148	154	157	134
157	Santa Cruz - Bolivia	157	152	150	98	96	180	167	170	176	150
158	Amman - Jordan	158	170	169	153	151	145	98	132	167	164
159	Mumbai - India	159	114	170	168	171	140	171	116	159	116
160	Rabat - Morocco	160	143	182	137	144	174	159	176	108	166
161	Johannesburg - South Africa	161	145	129	181	155	161	152	120	142	165
162	Asuncion – Paraguay	162	168	152	106	106	164	178	165	170	139
163	Bangalore - India	163	111	155	123	175	131	177	112	165	175
164	Guayaquil - Ecuador	164	179	163	92	112	173	163	159	169	148
165	Tehran - Iran	165	174	121	180	147	147	121	147	145	171
166	Salvador - Brazil	166	175	147	164	123	159	147	172	160	163
167	Munich - Germany	167	141	175	157	157	179	160	161	118	158
168	Seoul - South Korea	168	144	171	160	140	151	118	146	180	180
169	Chicago - USA	169	176	161	167	117	134	176	173	156	170
170	Guatemala City - Guatemala	170	147	164	161	170	167	128	143	179	169
171	Kolkata - India	171	130	167	171	169	144	162	169	174	178
172	Douala – Cameroon	172	180	174	120	137	182	140	140	182	161
173	Manila - Philippines	173	164	137	172	177	155	169	101	158	176
174	Cairo - Egypt	174	181	154	170	166	178	132	141	154	174

Appendix A (cont.). Rating of Cities according to the Cities in Motion Index (CIMI) and its Components

#	City	Cities in motion	Economy	Human capital	Social cohesion	Environment	Governance	Urban planning	International profile	Technology	Mobility and transportation
175	Kampala – Uganda	175	163	183	152	174	172	142	166	177	162
176	Caracas - Venezuela	176	182	111	183	109	166	179	137	181	136
177	Lahore - Pakistan	177	161	178	165	179	183	126	183	178	142
178	Accra - Ghana	178	183	177	166	168	146	170	157	173	156
179	Karachi - Pakistan	179	162	176	182	181	181	137	182	172	168
180	Lagos - Nigeria	180	177	172	178	178	163	180	178	183	183

Source: IESE Cities in Motion Index 2022.

Appendix B. Distribution by Clusters in the Statgrahics Program

Label	Cl.	Label	Cl.	Label	Cl.
London - UK	1	Baltimore - USA	2	Florence - Italy	6
New York – USA	2	Leeds - UK	3	Tianjin – China	5
Paris – France	1	Wellington - NZ	3	Medellin – Colombia	8
Tokyo – Japan	1	Nottingham - UK	3	Nur Sultan – Kazakhstan	8
Berlin – Germany	1	Tallinn - Estonia	3	Baku – Azerbaijan	8
Washington – USA	2	Antwerp - Belgium	6	Cape Town - South Africa	7
Singapore - Singapore	1	Detroit - USA	2	Lima – Peru	8
Amsterdam - Netherlands	1	Santiago – Chile	4	Santo Domingo - Dominican Republic	8
Oslo – Norway	1	Marseille - France	6	Kuwait City – Kuwait	8
Copenhagen - Denmark	1	Quebec - Canada	3	Sarajevo - Bosnia-Herzegovina	8
Munich – Germany	1	Lisbon - Portugal	3	Skopje – Macedonia	8
Seoul - South Korea	1	Phoenix - USA	2	Cali – Colombia	8
Chicago – USA	2	Nagoya - Japan	6	Delhi – India	8
Zurich - Switzerland	1	San Antonio - USA	2	Riyadh - Saudi Arabia	8
Vienna – Austria	1	Osaka - Japan	3	Manama – Bahrain	8
San Francisco - USA	2	Nice - France	6	Jakarta – Indonesia	8
Hamburg - Germany	3	Lille - France	6	Curitiba – Brazil	8
Dublin – Ireland	3	Budapest - Hungary	4	San Jose - Costa Rica	8
Rotterdam - Netherlands	3	Valencia - Spain	3	Quito – Ecuador	8
Helsinki – Finland	1	Bratislava - Slovakia	6	La Paz – Bolivia	8
Label	Cl.	Label	Cl.	Label	Cl.
Toronto – Canada	2	Linz - Austria	6	San Salvador - El Salvador	8
Los Angeles – USA	2	Las Vegas - USA	2	Tunis – Tunisia	8
Seattle – USA	2	Duisburg - Germany	6	Brasilia – Brazil	8
Boston – USA	2	Tel Aviv - Israel	6	Santa Cruz – Bolivia	8
Stockholm – Sweden	3	Istanbul - Turkey	4	Amman – Jordan	8
Hong Kong – China	2	Malaga - Spain	6	Mumbai – India	8
Madrid – Spain	1	Riga - Latvia	6	Rabat – Morocco	8
Bern – Switzerland	3	Seville - Spain	6	Johannesburg - South Africa	8
Basel – Switzerland	3	Vilnius - Lithuania	6	Asuncion – Paraguay	8
Houston – USA	2	Turin - Italy	6	Bangalore – India	8
Barcelona – Spain	1	Ljubljana - Slovenia	6	Guayaquil – Ecuador	8
Manchester - UK	3	Wroclaw - Poland	6	Tehran – Iran	8
Reykjavik – Iceland	3	Zagreb - Croatia	6	Salvador – Brazil	8
Taipei – Taiwan	3	Guangzhou - China	5	Casablanca – Morocco	8
Edinburgh - UK	3	Buenos Aires - Argentina	4	Nairobi – Kenya	8
Sydney – Australia	1	Kuala Lumpur - Malaysia	7	Belo Horizonte – Brazil	8
Beijing – China	2	Palma de Mallorca - Spain	6	Guatemala City – Guatemala	8
Melbourne - Australia	1	A Corua - Spain	6	Kolkata – India	8
Lyon – France	3	Zaragoza - Spain	6	Douala – Cameroon	8
Canberra – Australia	3	Shenzhen - China	5	Manila – Philippines	8
Frankfurt - Germany	3	Bilbao - Spain	6	Cairo – Egypt	8
Miami – USA	2	Bucharest - Romania	6	Kampala – Uganda	8
Prague - Czech Republic	3	Murcia - Spain	6	Caracas – Venezuela	8
Cologne – Germany	3	Porto - Portugal	6	Lahore – Pakistan	8
Montreal – Canada	3	Abu Dhabi - UAE	5	Accra – Ghana	8
Dallas – USA	2	Mexico City - Mexico	4	Karachi – Pakistan	8

Appendix B (cont.). Distribution by Clusters in the Statgrahics Program

Label	Cl.	Label	Cl.	Label	Cl.
Geneva - Switzerland	3	Jerusalem – Israel	6	Lagos – Nigeria	8
Stuttgart – Germany	3	Kyiv – Ukraine	6	Brussels - Belgium	4
Eindhoven - Netherlands	3	Bangkok – Thailand	7		
Ottawa – Canada	3	Sofia – Bulgaria	6		
Birmingham - UK	3	Panama – Panama	7		
Austin – USA	2	Athens – Greece	6		
Gothenburg - Sweden	3	Naples – Italy	7		
Denver – USA	2	Ankara – Turkey	6		
Vancouver - Canada	3	Belgrade – Serbia	7		
Shanghai – China	2	Doha – Qatar	5		
Milan – Italy	4	Montevideo – Uruguay	6		
San Diego – USA	2	Tbilisi – Georgia	6		
Auckland - NZ	3	Minsk – Belarus	6		
Philadelphia - USA	2	Almaty – Kazakhstan	8		
Liverpool - UK	3	Seo Paulo – Brazil	7		
Warsaw - Poland	4	Bogota – Colombia	7		
Dubai - UAE	5	Rosario – Argentina	8		
Dusseldorf - Germany	3	Ho Chi Minh City – Vietnam	7		
Rome - Italy	4	Cordoba – Argentina	8		
Glasgow - UK	3	Rio de Janeiro – Brazil	7		

Notes: Cl. – cluster number.