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Study of Smart Cities Based on Human Capital (Case of Russian Research-Driven Towns as Proto-Smart Cities)

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ABSTRACT

Existent philosophical literature has been largely focusing on the ethical aspects and controversies of developing and using smart technologies such as AI and big data, whereas human capital and infrastructural environment as pre-existing factors have been covered by AI Ethics in a lesser extent. Most of the current research focuses on technical infrastructural aspects in the implementation of complex "smart projects", while insufficient attention is paid to the role of social capital. In order to widen the focus and to include human capital and infrastructural developments coming along with the increasing role of AI, the paper takes a novel look at philosophical underpinnings of smart cities and discusses the concept of the Russian Naukograd (literally from Russian — City of Science, or Researchers' city, meaning a city which is developing as a community of scientists and academics) as a historical approach for smart city concept implementation. The authors apply theoretical methods of cognition (analysis, synthesis) as well as the case study approach to the Russian (Soviet) experience in forming research-driven cities in order to highlight the value of high scientific, industrial and educational capital ("smart nation") as a fundamental factor for the stable long-term development of modern cities. The findings suggest that some concepts of the Russian Naukograd for example the focus on research and education are valuable and that investment in social capital (i.e., people) should stand on the same footing as investment in technology developing a smart city. In this approach the prefix "smart" may stand for "smart citizens/nations" as a pivotal framework at the initial stages of smart cities development.

Keywords: Smart City; Science City; Research-Driven City; Technopolis; Urbanism; Information Technology; Social Capital; Smart Nation

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Исследование «умных городов» с точки зрения человеческого капитала (наукограды как прототип «умных городов»)

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АННОТАЦИЯ

Существующие научные исследования по вопросам разработки и использования высокотехнологичных решений, таких, как искусственный интеллект и большие данные, в основном фокусируются на этических аспектах и противоречиях, в то время как человеческий капитал и инфраструктура, традиционно являющиеся основополагающими факторами развития городов, охвачены этикой искусственного интеллекта в меньшей степени. Большинство современных исследований фокусируются на технико-инфраструктурных аспектах реализации комплексных проектов по внедрению «умных технологий», в то время как роли человеческого капитала уделяется недостаточное внимание. В целях расширения фокуса рассмотрения проблемы с точки зрения человеческого капитала как важного фактора развития городов, наряду с инфраструктурой и возрастающей ролью искусственного интеллекта, авторы по-ново-

му отражают концептуальные основы развития городов на примере российских наукоградов (буквально — «Город науки», или «Город исследователей», т.е. сообщество ученых и академиков) как исторического подхода к реализации концепции «умного города». Тематический подход к российскому (советскому) опыту формирования городов, ориентированных на исследования, подчеркивает важность научного, промышленного и образовательного капитала («умной нации») как фундаментального фактора стабильного долгосрочного развития. Полученные **результаты** свидетельствуют о том, что фундаментальные основы российских наукоградов, например, фокус на исследования и образование, являются ценными для развития современных городов и что инвестиции в социальный капитал, т.е. в людей, должны находиться на том же уровне, что и технологические инвестиции, благодаря которым развивается «умный город». При таком подходе приставка «умный» может означать «умные граждане/сообщества» в качестве ключевой основы на начальных этапах развития концепции «умный город».
Ключевые слова: умный город; наукоград; город исследователей; технополис; градостроительство; информационные технологии; человеческий капитал; умная нация

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INTRODUCTION

The growing economic and demographic relevance of modern cities poses completely new challenges for urban planning and management across the world. Increased migration and population density, rising housing prices, transportation, and environmental problems, changing demands of business communities and citizens urging for better quality of urban life present a series of challenges that a metropolis encounters nowadays. As a result, urban development management has been in constant search for new perspectives and concepts to manage and mitigate the ongoing tectonic shifts. In wake of the emerging discourse on AI and digitization, the spotlight has been largely shed on advanced technological solutions with the aim to create a digital urban environment that would handle emerging challenges, to meet the needs of all stakeholders (government bodies, businesses, and residents), as well as to provide more efficient integration of urban infrastructure elements. To embrace those changes, scientists coined the term "smart city". This concept has been interpreted in different ways, however, the core of any interpretation centres on information and communication technologies that qualitatively improve and simplify the daily processes of urban life and help solve problems through citizens' engagement. Although smart cities have been widely discussed in literature, the role of the inhabitants in smart cities has been discussed in a lesser extent. Do smarter cities require smarter individuals? What kind of individuals should smart cities be designed for and will the inhabitants of those cities will adapt to the changes coming along with the role out of technical solutions?

The role of human beings in the development of the entire city community stems from ancient philosophy. The Greek world "polis", which has the meaning of city, but also of political organization in general, referred rather to political entities with a smaller territory. This is not surprising and owes to the fact that the perpetual striving of city-states for regional hegemony characterized Greek civilization before the advent of Hellenism and not the establishment of large empires. Consequently, the works of Plato and Aristotle have to be seen in this specific civilizational context [1]. However, Greek philosophy did not substitute the notion of the state with the polis, merely because of the absence of larger political structures. Plato's thoughts deliberately focused on the city as centre of human interaction and even included detailed provisions for the perfect number of inhabitants or the right arrangement of the city's fortifications. Besides, Plato and Aristotle shared some essential views on the intrinsic value of human co-existence and the purpose of the city to provide individuals with a "healthier" and "happier life" [2]. While Plato argued in the Politeia that the "smartest ones" should be in charge governing the city, Aristotle envisioned a political system based on "checks" and "balances" and a strong middleclass as the most stable and reliable political constitution. The Aristotelian approach was based on the socio-economic exclusion of a sizeable part of the population conflicting with modern assumptions on just and fair policies. Although both enlightenment and contemporary philosophy have challenged many of the views and concepts established by Plato and Aristotle, we still

ground our future-driven research on their views and thoughts to carve out moral and philosophical purpose of smart cities. Plato and Aristotle have elaborated on the mission statement of the city and have put the role of human beings at the centre of their considerations [3].

The current stage of urban development is characterized by the rapid introduction of innovative and "smart" technologies to improve the well-being of citizens, respond to global challenges, and enhance governance. However, practice has shown an orientation towards economic incentives for the introduction of novel technological solutions, where less attention is paid to the level of education and qualifications of citizens [4].

So, the **hypothesis** states that development of modern "smart cities" should primarily focus on investment in human capital rather than economic incentives solely related to building technological infrastructure. The **research goal** is to examine the Russian concept of Naukograd as one of the approaches to shaping the human capital in the context of urban governance with its application in smart cities.

The paper is structured as follows: theoretical underpinnings of the role of citizens in modern smart city governance, the analysis of Russian approach to research-driven cities, the current state of research-driven cities' development as well as the cases of smart solutions' implementation.

MATERIALS AND METHODS

The character of a modern city is multidimensional and complex. The studies on this topic have long ceased to be the domain of architects, planners, economists, utilities, etc. Specialists, developing cities, can no longer remain "narrow" professionals: they need interdisciplinarity, the ability to see the object volume, understand multiple and complex relationships and consequences. In addition, in a post-industrial society, the role of people, their interests and preferences are growing — they are gradually becoming existential for the development of certain territories and agglomerations. And the area itself is becoming increasingly interesting to more residents who want to participate in the process of development and improvement of their cities.

Currently the opportunities for city residents to participate in the formation of managerial decisions within the framework of the "smart city" concept are provided through a wide range of digital services integrated into a unified smart city infrastructure. In order to involve citizens in urban governance, it is necessary first of all to meet the tasks of popularizing and promoting the concept of a "smart city" among various groups of the population, providing technical opportunities for participation in urban management through online services and increasing the availability and openness of national and city data [5].

Residents of the city, living in an environment that is being digitally modernized influence the decision-making using city information portals through questionnaires that relate to the need to introduce certain technologies, or the assessment of citizens' opinions regarding certain areas [6]. With the help of the citizens' appeals functions, residents have the opportunity to pay attention to any urban problems or offer their initiatives. Based on the information received, after surveys and studying appeals, the city authorities can form a strategy for the modernization of certain domains of the urban economy [7]. It provides an opportunity to increase the degree of involvement of city residents in urban management, as well as to allow the governance bodies to increase the openness and accessibility of information taking into account the citizens' applied needs.

Besides it is important to take into account that the "admittance" of citizens to influence managerial decision-making should also be fundamentally worked out. Urban governance is a multidisciplinary field that requires a number of competencies, therefore, citizens must have the appropriate (minimum) skill levels. The development of smart cities is increasingly based on the principles of knowledge management. This leads to new management challenges that reflect the complexity of governance and process problems in smart city projects, as well as the need for knowledge management that arise both inside and outside the project boundaries.

In dealing with smart city governance issue when internal knowledge is managed, scientific force usually acts as knowledge intermediaries, while they act as knowledge gatekeepers when governance relationships involve external knowledge. Moreover, they act as knowledge providers in the process of knowledge creation within the boundaries of smart city projects and they may have an important role as evaluators of knowledge residing outside projects' boundaries [8]. Such integration efforts require smart city projects to

be composed of public and private players, the academia, and the wider community [9]. This increases the pool of available knowledge and the possibility to address the development of smart city initiatives from multiple perspectives [10]. Knowledge is not a static resource, it entails a continuous, dynamic management of processes of creating, integrating, and applying knowledge out of knowledge [11]. These processes also have different ultimate objectives and are primarily managed by different organizations/actors, which may change over time according to the specificity of related goals. Accordingly, novel knowledge and solutions to address a city's specific needs must be created before initiating a smart city project. Here attention is placed on the actors involved and their contribution to each process, with particular regard to the academic sector. Indeed, the academia is often viewed as the creator of scientific knowledge, although it may increasingly play a crucial role in the validation, transfer, and application of knowledge.

Just like any organization or innovative ecosystem, smart city projects include knowledge that resides within and beyond their boundaries. In other words, according to the open innovation paradigm [12], the development of smart cities can be driven by combining knowledge generated and owned by projects partners with knowledge that originates elsewhere. In fact, on the one side, smart cities necessitate that governments and citizen provide the local knowledge to shape cities with respect to local resources, priorities, values, and needs [13]. Likewise, firms and universities working on smart city projects are asked to contribute with their technical and scientific know-how to the development of smart cities [14].

Therefore, the authors apply the methods of theoretical analysis and a case-study approach to the Russian (Soviet) concept of "Naukograd" as the prototype of a smart city, which is primarily based on its social capital, and the introduction of technological infrastructure is driven by the stages of scientific and technological development of the city as an integral ecosystem.

RESULTS

In the Russian context, the concept "Naukograd" (used only in Russia) was coined in the early 1990s and signified an emergent city where knowledge-intensive industries and scientific organizations are at the frontline of its growth strategy. In 1999, the Federal Law was adopted to regulate the process of assigning the status of Russian Research-Driven City to municipalities that comply with established criteria and agree on specific development program[1]

Although the term Naukograd has found its entry in Russian law in the 1990s, it depicts a unique phenomenon in the history of world science and is based on pre-existing historical experiences and perceptions. Leninist philosophy itself had a strong focus on education and literalization was one of the most important pillars of Socialist education policies in developing countries. In the context of higher education and genuine research, the concept is associated with the Soviet era of research and innovations development when under the soviet administrative principles, most of these "restricted access" cities were established in the area of functional municipalities to resolve complex issues of the defence industry (*Figure*). The main idea behind this concept was to create a space for scientists and for intellectuals to exchange and to create a place where smart people interact with each other. The best scientific and research personnel of the country lived and worked in such cities, the model of reproduction of highly skilled specialists was created by launching subsidiaries of industry-specific institutes. This connects to the moral general notions of Socialism such as the idea of an avant-garde, which is leading technological, cultural, or political progress or the strong focus on the promotion of sciences.

SPECIALIZATION OF RUSSIAN SCIENCE CITIES

State incentives notwithstanding, opacity and secrecy have led to negative consequences, which still can be observed to some extent today. For example, the state was the only consumer of products and scientific developments of such cities. After the fall of the Soviet Union, Naukograds were declassified, and their functions were redirected to the use of existing potential for the development of regions of the country, particular cities, and the whole country. At the same time, links of cooperation with other regions or countries were not developed since planning and activities of Research-Driven Cities were carried out from the Federal Centre or in Soviet times from the Union Centre As mentioned, the exclusiveness of many smart cities

[1] Federal law of the Russian Federation "On the status of Naukograd of the Russian Federation of April 7, 1999 No. 70-FZ. URL: https://base.garant.ru/180307/

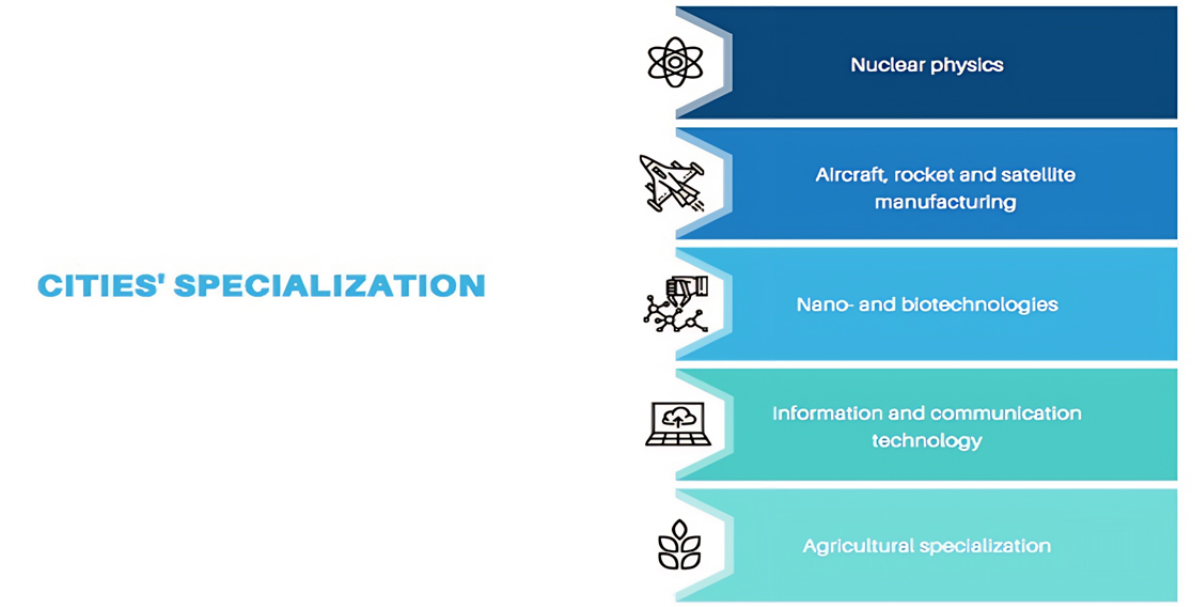

Fig. **Specialization of Russian science cities**

Source: Compiled by the authors based on [15].

also contributed to their relative isolation within the country. Drastic cuts of government funding for research and development and turbulent military-industrial sector in the 1990s led to decline of socio-economic status of Naukograds. Major city employing businesses were not able to provide their workers with a decent income. Therefore, there was a migration of highly qualified specialists and economically active population from Naukograds not only to nearby regional centres, but also abroad (the so-called brain drain).

Nevertheless, Russian case of Naukograds played a crucial role in shaping the pillars of innovations' system in the Russian Federation in terms of conditions for innovative business, new technologies and production of competitive high-tech products, including import substitution products. It was an effective innovation environment for advancing scientific ideas and production development. Naukograds' contribution also consists of:

- creation and development of a creative municipal education management system as a means of fulfilling the city's socioeconomic development objectives;
- facilitating the entry of high-tech investment projects into the municipal entity in scientific and technical clusters;
- life-long learning frame-setting;
- enabling advanced fundamental R&D of new goods;
- producing assets for national defence purposes, the economy, foreign policy, and other security-related issues;
- production of goods for the sake of national defence, the economy, foreign policy, and other national security-related topics;
- safeguarding the advancement of fundamental science, higher education and the monetisation of information learned through the creation of high-tech enterprises.

The overall Naukograds development policy is presently aimed at exploiting the existing scientific and innovative potential of Naukograds to realize the goals and objectives of the country's development, as well as to ensure the attractiveness for Russian and foreign leading scientists and young promising researchers, the development of the social capital of Naukograds.

Comparing the traditional approach to smart city with the Russian notion of Naukograd, there are explicit differences in terms of centralization and decentralization. Although the Russian model of smart cities driving from Socialism and the Western model deriving from market liberalism are both based on the notion of enlightenment that progress constitutes a major aim of policymaking, there are

some striking differences. Russian Naukograds were primarily designed as a centralized place to create knowledge based on mutual exchange. The Russian focus was therefore not so much to incentivize smart people by material interests, but rather by professional skills and social promotion. The notion of a scientific-avant-garde played therefore a crucial role for comprehending the Soviet model. Similar aspects can be observed in the promotion of scientists in other socialist societies such as North Korea or Cuba. As a result, Russian Naukograd focused rather on the investment in people (education and spill-over effects) than on investment in technologies or infrastructural aspects. The powerful and resourceful teams capable of finding a quick solution to scientific and technical issues were guaranteed by the "import" of highly qualified specialists from other regions. The need for the training of young staff by research centres was satisfied by special departments of the country's leading universities. This contrasts with the American approach to the Silicon Valley, which was rather based on a decentralized system. The emergence of the Silicon Valley with its start-up culture and universities is a perfect example of the interplay for these forces. In contrast to the Russian case, the notion of incentives and the cooperation between private companies currently represented by the likes of Amazon, Microsoft, Facebook, and Alphabet played an extra-ordinary role in shaping the Silicon Valley, including the many start-ups which emerged in the vicinity of the tech industry. Another pivotal difference concerns the mode of interaction in these smart cities. While the technologies in the West developed against the background of a liberalized labour, capital and specifically real estate markets, Russian science cities were based on state planning of all these areas.

The prioritization of investment in human beings characterizes the Russian definition of Naukograd and the criteria for obtaining that status, which include the following criteria:

- share of employees in R&D sector should be minimum 20% of total employment in the city's economy;
- share of researchers should exceed 20% of the total employment within the R&D sector;
- R&D companies' turnover should constitute minimum 50% of the total city's economic turnover.

Based on the mentioned definition, 13 cities have the status of Naukograd of the Russian Federation: Biysk, Koltsovo, Pushchino, Troitsk, Dubna, Reutov, Zhukovsky, Korolev, Fryazino, Obninsk, Michurinsk, Protvino, Chernogolovka. Looking at the size of these areas, one can see that individuals were detached outside of the epicentre to conduct research far away from distraction creating an interesting habitat with the smart people.

Table presents data of Russian Naukograds' requirements implementation monitoring as of 2021.

The above-mentioned requirements give enough evidence to conclude that the Russian (Soviet) approach was to invest in human capital, that is, to gather and form intelligent (smart) people capable of further creating technological solutions for the benefit of the entire society. In addition, relying on statistics, it's evident that Naukograds still fulfil the established requirements, which indicates that in the scientific and industrial system of the Russian Federation Naukograds remain one of the most important engines of innovative development. The existing scientific and innovative potential of Naukograds should be used to realize the goals and objectives of the development of the Russian Federation, as well as to ensure the attractiveness of employment in Naukograds for Russian and foreign leading scientists and young promising researchers, the development of the human potential. Thus, such initiatives may also develop into the formation of a "smart city" (where prefix "smart" stands for qualified people).

At the same time, the development of Naukograds as "smart cities" is influenced by the following factors:

- Fundamental scientific and educational institutions: the presence of universities, research centres, laboratories which play an important role in the formation of educational and research framework;
- Introduction of innovative technologies that fundamentally change the structure and principles of the main economic processes;
- Environment and quality of life: smart cities should be comfortable for life with quality infrastructure, public spaces, high safety and sustainable environment;
- The life cycle of the population: the population of the city should be diverse in age and social aspects, covering people of all ages and social groups;
- Governance and public participation: A smart city should be a product of interaction between local authorities, entrepreneurs and the community;
- Economic growth: Smart cities should have a developed economy and be able to generate highly-qualified employment.

Table

Statistics on the activities of Naukograds scientific and industrial complex in 2021

Naukograd	Number of entities	The total number of employees	Number of researchers	Number of professors and lecturers	The total volume of goods and services produced (millions of US dollars)	The cost of investments in fixed assets (millions of US dollars)
Biysk	10	4026	632	246	288.3	7.6
Dubna	26	12 322	2039	564	618.9	21.1
Zhukovsky	7	10 564	4372	0	398	34
Koltsovo	6	4237	1432	5	378.4	24.2
Korolev	14	23 339	7506	327	2019	64.6
Michurinsk	12	5604	1237	351	145.9	2.9
Obninsk	39	12 863	3025	217	996.6	53.4
Protvino	11	2401	903	67	118.5	3.1
Pushchino	25	1887	1096	110	55.1	5.3
Reutov	6	4477	1808	62	870.5	36.7
Troitsk	18	2668	1286	78	127.2	28.8
Fryazino	18	11 417	2330	194	918.2	16.7
Chernogolovka	13	3555	1317	41	111.8	8.7

Source: compiled by the authors based on report on the assessment of compliance of indicators by Naukograds' scientific and industrial complexes with the requirements established by Federal law in 2021. Ministry of Science and Higher Education of the Russian Federation. 2022. URL: https://minobrnauki.gov.ru/upload/iblock/278/32o3d3q3pdxr7qep8govhw57dij9g3gx.pdf (accessed on 15.11.2022).

The "Economic indicators of Russian science cities" (*Appendix, Table*) presents the main socio-economic indicators of Russian Naukograds in comparison with the regions of the Russian Federation. The presented data indicate that investment in social sphere dominates the overall structure of budget spendings. These data confirm the hypothesis that Naukograd governance policy first of all asumes investments in social capital, not infrastructure.

So, the Russian case can be considered as an alternative co-existing approach to smart city development in terms of forming a "smart nation".

DISCUSSION

The Russian model of Naukograds concentrates on the role of scientists, which is why the integration of smart technologies in those places requires a special attention. When reflecting on the history of Naukograd, some scholars posit the existence of a universal cycle- or waves-like pattern of research-driven generations [16]:

- The First Wave — new purpose-built cities within the state policy on the development of fundamental science and technology, usually lacked a strong urban character and carried a certain level of confidentiality.
- The Second Wave — applied research centres created in the city outskirts that provide innovative development opportunities for industrial clusters, technoparks, technopolis.
- The Third Wave — contemporary cities of science designed to ensure growth through the progress in science and development of technologies characterized by a high level of social inclusion and cooperative ties between various subjects of innovative activity — universities, authorities, businesses, and public organizations.

Soviet science cities belonged to the first wave and were established to resolve scientific and technological issues incurred by the government, in particular in the area of defence. The smart city concept is well reconciled with the third wave, not only because of its technological effectiveness, but also due to being human-centric. In fact, it is to the third wave that Russian research-driven cities must strive for. Prior studies generally confirm that the challenge of using the unique potential of science cities is of national importance as it may lead to a quality change in the Russian urbanization [17]. On top of that, innovative development of the economy nowadays heavily depends on preservation and effective use of the rich scientific, technical, and intellectual capabilities of these cities [18, 19].

As previously mentioned, the Russian Naukograds rather centered on investment in people and not so much in technologies, which is evident in terms of digitization of Russian Naukograds. Naukograd cities have taken on increased obligations for the project implementation and will fulfil not only the basic requirements of the Russian Smart City standard, but also other digitalization incentives in the spheres of governance, utilities, transportation, environment innovations, etc. All these directions are reflected in the standard.[2] In order the cities pioneering this concept, the Russian Ministry of Construction provides methodology and administrative support. The Ministry of Construction also created the "Cities IQ" index (rating), which determines the digitization level of urban areas as well as applicability of smart solutions that municipal entities implement. "Cities IQ" ranks cities basing on evaluation of the dynamics in the following key areas: intelligent public and environmental safety systems, smart utilities, urban environment advances, smart urban transportation, tourism and service, intelligent public services systems, economic status and investment climate, communications network infrastructure. The index shows that in 2021 there is an evident progress in the digitalization of Naukograds, however the coverage across the country is heterogeneous. Korolev (83 points) and Zhukovsky (79 points) are leading in their subgroup of most populated small towns, Dubna (78 points) and Koltsovo (71) showed average results, Biysk (58 points) and Obninsk (60 points) are still at the beginning of their digital path. In this regard, we validated the presence of smart technologies and solutions for citizens comfort which are introduced into the everyday life of a Naukograds.

It is crucial to note the advantages of the classic Naukograd model over the "framework" factors, which attribute cities to the class of "smart". These factors inherently reflect an approach to focusing on investments in human capital rather than infrastructure:

1. Concentration of scientific and technological institutes and enterprises: Naukograds are inherently powered by large scientific centers and high-tech enterprises, which can contribute to the innovative development of the region and facilitate the transfer of knowledge between scientific institutes;

2. Better access to highly qualified specialists: Naukograds are usually located close to major universities and other educational institutions, which facilitates access to highly qualified specialists and talented students;

3. Opportunities for research and development: thanks to the concentration of institutes and enterprises Naukograds provide opportunities for conducting research and development (R&D) at a new level and to a far greater extent than smart cities;

4. Creating a community: the possibility of placing people working in the same industry next to each other can help establish connections and create networks of professionals.

The Russian case is notable and shows that the integration of smart technologies has proved more difficult to obtain than in the case of the Silicon Valley or in the case of China's Shenzhen, where technological adaption has been faster, and where smart city hubs were connected to large business centres and not placed in remote areas rendering the costs of technological change higher. Besides, the existing major Russian private IT companies have not settled in Naukograds, but rather maintained their presence in the capital cities Moscow and Sankt Petersburg. This strikingly differs from the USA case, where most companies are headquartered in tech hubs and not in political or administrative centres. As a result, the most pressing issues has concerned financing, as the absence of commercial partners enhances the cost for the state budget. Under the existing funding mechanism, the federal transfers are determined in the proportion of Naukograd's permanent population,

[2] Basic and additional requirements for smart cities (Smart City standard) Ministry of Construction and Housing and Communal Services of the Russian Federation. 2019. URL: https://minstroyrf.gov.ru/upload/iblock/74f/Standart.pdf (accessed on 18.05.2022).

while the size of the territory of urban districts and the state of infrastructure are disregarded [20]. The resources needed for smart city are not only necessary for providing incentives to skilled labour, but also for investment in the technical infrastructure.

In the Russian case, there has been some progress in adapting technologies in these areas. In Biysk, in the context of the Smart City project, the transport portal "Bus22" together with its mobile version was created to track online the trajectories of public transport. Citizens who use public transport could pay for travel using a bankcard or a social card of a city resident.[3]

Dubna has opened a municipal regional management centre, which is integrated with the Smart City competence centre. Its employees are engaged in online monitoring of the housing and utility sector, power, healthcare, and education, and are efficient at tackling city's problems.[4] Smart stops appeared in Zhukovsky. The objects are equipped with CCTV cameras, connected to the "Safe Region" System, equipped with extra lighting, free Wi-Fi, and USB ports for recharging portable devices.[5] More than that, the first Centre for Prototyping and Digital Technologies in the Moscow Region also operates in Zhukovsky, where the development and manufacture of various products for the Russian industry based on additive technologies and 3D printing takes place.[6] In Koltsovo a system using the Internet of Things is being deployed. The city is developing a network of smart energy-efficient LED lightings which cover 70% of Koltsovo streets and 80% of the adjacent areas.[7] "Digital Korolev" is a program that integrates on the basis of computer systems, digital communication channels and sensors programs in the field of healthcare, housing and utility services and getting feedback from citizens. It is designed to improve and upgrade the management processes.[8]

Michurinsk has implemented a number of projects in the area of modern technologies introduced in the urban economy and tourism. These are information boards at stopping points, temperature controllers in apartment buildings, digital model of the city and intelligent video.[9] Obninsk was the first settlement of the Kaluga region to adopt an automated metering system for housing and public utilities — smart meters, which provide greater transparency of utility bills and relieve residents of apartment buildings from inconvenience of manually transmitting data.[10] "The Smart City" company is functioning in Protvino: the main activity is the creation of automated technological control systems for various sectors of the housing and utility services and the entire management complex of the municipality. Development strategy of Pushchino ensures activities for improvement of city management, for instance, online interaction of the administration with residents through a single citywide information portal and implementation of IT projects under the concepts of "Smart City", "Safe City", "Open Data" and "E-Government".[11] In Troitsk a Smart Grid technology program is being implemented to increase

[3] How to turn a science city into a smart city. Official website of the Biysk Municipality. 2019. URL: https://biysk22.ru/about/info/news/? ELEMENT_ID=4085 (accessed on 20.11.2022).

[4] The implementation of the "digit" in the life of the city was discussed in Dubna. 360TV. Nov. 27, 2019. URL: https://360tv.ru/news/mosobl/vnedrenie-tsifry-v-zhizn-goroda-obsudili-v-dubne/ (accessed on 22.08.2022).

[5] "Smart stops" with Wi-Fi installed in Zhukovsky. Interfax Russia. Aug. 30, 2019. URL: https://www.interfax-russia.ru/center/novosti-podmoskovya/umnye-ostanovki-s-wi-fi-ustanovili-v-zhukovskom (accessed on 08.03.2022).

[6] The Center for Prototyping and Additive Technologies opened in Zhukovsky. RIAMO. Dec. 12, 2019. URL: https://riamo.ru/article/400366/tsentr-prototipirovaniya-i-additivnyh-tehnologij-otkrylsya-v-zhukovskom.xl (accessed on 13.09.2022).

[7] The Smart City system in Koltsovo will cost more than 200 million. Vesti Novosibirsk. Sep. 17, 2020. URL: https://www.nsktv.ru/news/city/sistema_umnyy_gorod_v_koltsovo_oboydyetsya_v_bolee_chem_200_millionov__170920191906/ (accessed on 18.09.2022).

[8] The digital management program is planned to be implemented in Korolev as part of a development strategy. Moscow Region Government. May 17, 2019. URL: https://mosreg.ru/sobytiya/novosti/myn-obrazovaniya/korolev/intervyu-programmu-cifrovogo-upravleniya-realizuyut-v-koroleve-v-ramkah-strategii-razvitiya-8689 (accessed on 26.09.2022).

[9] Michurinsk presented achievements in the Smart City project implementation. Science City Michurinsk. Mar. 28, 2019. URL: https://мичуринск-наукоград.рф/news/2019–03–28/michurinsk-prezentoval-dostizheniya-v-sfere-realizacii-proekta-umnyy-gorod (accessed on 15.10.2022).

[10] Telemetry from Rostelecom brought comfort to Obninsk's homes, and savings to families. KP40.ru. Oct. 19, 2018. URL: https://www.kp40.ru/site/releases/company/52760/ (accessed on 11.01.2023).

[11] Science city Pushchino submitted a development strategy for approval by the Scientific and Technical Council. Ministry of Investment, Industry and Science of the Moscow Region. 21.10.2016. URL: https://mii.mosreg.ru/sobytiya/novosti-ministerstva/naukograd-puschino-vynes-na-utverzhdenie-nauchnotehnicheskogo-soveta-strategiyu-razvitiya-20161021 (accessed on 15.11.2022).

transmission speed of large volume of data covering operation of substation equipment and power lines and, as a result, make the system more reliable. The facilities are equipped with advanced equipment, thanks to which dispatchers can prevent violations and quickly perform the required actions [21].

The "Istok-Audio" company from Fryazino has a unique design — a smart home for hearing-impaired people, which will make their life more comfortable. In such a house, smoke, moisture, and sound recognition sensors are installed — including a crying baby, a doorbell and speech on the TV.[12] The company "ArtEX" developed several systems specifically for digitalizing the housing and communal services sectors, so that each of them — power, water, and heat supply — cooperate flexibly [22].

An important implication of these findings is that Naukograds presently show adaptability of science-driven approach to city governance in terms of smart city projects implementation. That is to say that such governance structure of the city allows to successfully implement smart solutions in various spheres of life of society, which is now also one of the strategic objectives of Naukograds' long-term development.

CONCLUSION

Western philosophy as envisioned by Plato and Aristotle has traditionally highlighted the city as the natural place of human interaction and focused on intellectual and not mere technological growth. The research-driven cities of the Russian Federation reconnect to this idea and can be a significant local form of organization of innovative activity and the growth factor of the new digital economy. Naukograd would play a pivotal role in the advancement of specific regions and the country as a whole. Moreover, they are based on the important notion that investment in persons plays a more important role than in technologies.

Although Naukograds provide a unique background for scientific collaboration, explicitly in the more remote areas of the Russian Federation, there are major shortcomings. One major aspect is here the low likelihood of spill-overs and the costly technological adaptation of new technologies. Besides, the national innovation and research system should be integrated to unite efforts of governing bodies at all levels, to organizations and businesses in the interests of accelerating use of science and technology. This is required to maintain and increase the future of research-driven cities in order to achieve national development goals and objectives. At the same time, the notion of Naukograd offers also some conceptional value for existing smart city development approaches rather based on the notion of market forces, which ultimately result in a bottom-up process of technological evolution. The notion that technology requires some sort of concentration of resources and specific habitat for research and development might provide some added value for perspectives on smart city planning.

The case of Naukograds can also become a fundamental methodological basis for the smart city planners and developers. The main implication is the approach to the formation of a "smart nation" (qualified and educated), which creates the following innovative and technological value for the country:

1. Favorable conditions for the development of education and scientific potential, provides access to highly qualified specialists and specialized knowledge.

2. Attracting talent: Naukograds offer a favorable environment for attracting talented and ambitious people. They provide the best conditions for research and creative activity, as well as opportunities for career growth and professional development. This attracts scientific and intellectual leaders, who in turn contribute to the economic and cultural development of the city.

3. Cooperation and innovation: Conditions for cooperation between scientists, researchers, students, and entrepreneurs are created in Naukograds. This promotes the exchange of knowledge and experience, joint research, and projects, as well as the development of innovations. Such cities can become centers for the development of new technologies, scientific discoveries, and progressive solutions in various fields.

4. Economic development: Naukograds focused on human capital have the potential to develop a knowledge economy. Highly educated specialists create innovative products and services that can become the basis for economic growth and attract investment. In addition, scientific and research institutes can become centers for attracting foreign investors.

[12] Fryazino's company introduced a smart home for the hearing impaired to Japanese delegation. 360TV. Jan. 30, 2018. URL: https://360tv.ru/news/nauka/frjazinskaja-kompanija-predstavila-delegatsii-iz-japonii-umnyj-dom-dlja-slaboslyshaschih/ (accessed on 25.11.2022). (In Russ.).

All these factors make Naukograds attractive for the development of human capital and contribute to the creation of a favorable environment for scientific and intellectual achievements.

It's worth noting that the approach to view a smart city from the perspective of a "smart nation" for the development of a city is not opposed to a technology-driven approach, rather complementing it, and suggesting that smart governance should be also considered in terms of a focus on social capital. Such an approach is applicable both in the development of smart cities "from the ground-up" and for cities where a certain technological infrastructure has already been established.

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Appendix

Table

Russian Naukograds' economic indicators

Naukograd/region	Population	Income per capita (US dollars)	Investments in fixed assets (thousands of US dollars)	Contribution of the city to the region's total investments in fixed assets	Total income (thousands of US dollars)	Contribution of the city to the region's total income	Budget expenditures on ICT and digital technologies (DT) (thousands of US dollars)	Contribution of the city to the region's budget expenditure on ICT and DT	Budget expenditures on social sphere (thousands of US dollars)	Contribution of the city to the region's budget expenditure on social sphere
Obninsk	129584	608	133	0.01%	71190	10.23%	268	0.23%	12601	53.99%
Kaluga Region	342936	443	1620253		695722		118291		23339	
Koltsovo	17465	784	28177	2.33%	10150	0.26%	82	0.01%	765	1.64%
Sverdlovsk Region	4239161	509	1207595		3967386		577507		46505	
Michurinsk	90451	509	32729	3.27%	10002	1.62%	615	1.35%	552	2.81%
Tambov Region	966250	382	1000000		617109		45608		19681	
Biysk	196442	1378	2000	0.13%	1633	0.18%	19	0.02%	2265	5.21%
Altai Region	2333800	329	1574684		916139		99848		43496	
Protvino	36985	700	27127	0.87%	11006	3.71%	131	0.24%	496	5.77%
Zhukovsky	110507	880	22614		36013		63		59	
Korolev	224248	915	143		23051		96		396	
Dubna	74193	656	1827		40832		593		44	
Pushchino	19392	720	1359		5879		262		5285	
Troitsk	70301	629	3119		46161		185		4661	
Fryazino	60580	961	62444		15866		831		832	
Chernogolovka	22627	866	1783		17222		702		567	
Reutov	147000	827	2676		53165		156		415	
Moscow Region	8591736	680	14101265		6725151.9		1278050		221084	

Source: compiled by the authors based on the data of Rosstat. URL: https://eng.rosstat.gov.ru/folder/75924