

Scientific concept of intelligent cyber-physical technopolis

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Abstract. Theoretical concepts for the formation of an intelligent cyber-physical technopolis, an innovation-active cluster, and the provision of economic security for a depressed area are being studied. The evolution of the technopolis paradigm has been systematized over more than forty years. Three stages of the technopolis paradigm development have been identified: the first stage from 1983 to 1990, the second stage from 1990 to 2000, and the modern, third stage from 2000 to the present. Characteristics of the evolution of the technopolis paradigm are provided from the perspective of the conditions for development and the strategies for the implementation of technopolises. Key terminological constructs of the considered concept, such as technopolis and innovation-active cluster, are examined. A conceptual scheme of the "technopolis wheel" is presented, which broadly includes three key segments: networks and connectivity, investment capital, and innovation and R&D. It is shown that the key segments of the technopolis wheel are revealed based on seven components, connected by influencing agents. Four factors of technopolis development are identified. The concept of the technopolis wheel has important implications for the formation of a system-forming innovation-active cluster to enhance the economic security of the region. The main directions for further development of the technopolis paradigm are considered to be the need to create technological sovereignty under conditions of global competitiveness, distributed collaborative forms of cooperation based on networks, platforms, and ecosystems, the establishment of intensive partnerships based on the fivefold innovation spiral, and the creation of "smart" megacities in the intelligent economy.

1 Introduction

The interrelationship between technology and economic development in new type city-states is a new global phenomenon that began in the 1980s [1-4] when Japan initiated the development of the technopolis concept. The technopolis plan was designed to maintain the country's technological standard at the highest level in the future, improve technological

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development, and create new jobs in regions, and became one of the most important regional policies in world history.

The technopolis concept is a term that has emerged with the development of technology and is attracting increasing attention today thanks to the rapid development of innovations. Technopolis encompasses many aspects of modern society, such as economic growth, intelligent ("smart") systems, and sustainable development. The technopolis concept is also updated in line with technological development and issues of innovative digital technologies. Essentially, the technopolis concept must be applicable and useful to society in order to create an intellectual economy and increase its level of innovation.

To achieve the technopolis stage, various complex development programs are required. To support the technopolis, many resources are needed, primarily human, as well as natural resources. Essentially, technopolises directly indicate the reality that economic regional systems are undergoing profound changes in their structure and are conditioned in their growth dynamics by the interaction of three main, interrelated historical processes [5-7]. These three processes are technological revolution, the formation of the global economy, and the emergence of a new form of economic production and management that can be collectively called information.

The research aim is to systematize theoretical concepts for the formation of an intelligent cyber-physical technopolis, an innovation-active cluster, and the provision of economic security for a depressed area.

The research objectives are:

- to determine the origins of the technopolis paradigm;
- to identify and characterize the evolutionary stages of the technopolis paradigm;
- to describe the terminological constructs of the technopolis concept;
- to comprehend the essence and content of the technopolis concept for the formation of a system-forming innovation-active cluster to enhance the economic security of the region;
- to identify the main directions for further research into the technopolis concept for the formation of a system-forming innovation-active cluster to enhance the economic security of the region.

2 Methods

The method used in this study is a literature review supported by relevant research. The aim of this method is to ultimately provide an understanding of the essence of the technopolis concept, the evolution of the technopolis concept over more than 40 years, and the role of the system-forming innovation-active cluster in enhancing the economic security of the region.

Through the literature review, the study examines the historical development of the technopolis paradigm, starting from its origins in the 1980s in Japan. The review also identifies and characterizes the different evolutionary stages of the technopolis paradigm over time. Additionally, the study explores the terminological constructs of the technopolis concept, including the definition of technopolis and innovation-active cluster. Moreover, the study aims to comprehend the essence and content of the technopolis concept for the formation of a system-forming innovation-active cluster to enhance the economic security of the region.

The literature review method is a useful tool for providing a comprehensive understanding of the technopolis concept, its historical development, and its implications for economic development and regional security. By analyzing and synthesizing existing research, this method can offer valuable insights and a more profound understanding of the technopolis paradigm and its role in regional economic development.

3 Results

The concept of technopolises was first developed in Japan in 1980 as part of the country's general industrial plan proposed by the Ministry of International Trade and Industry (MITI) following extensive discussions about the country's future industrial policy. The plan included six different strategies, one of which was the creation of technopolises based on the long-term vision for Japan's industrial policy. The proposal for technopolises was first made in "MITI's Policy Vision in the 1980s" [8] – a publication released by the Industrial Structure Council of MITI in March 1980. The plan became a government policy after the enactment of the Technopolis Law in 1983, also known as the Law for the Promotion of Regional Development Based on High-Tech Industrial Complexes [9]. The conditions stipulated in this law for a technopolis were that the minimum population should be 200,000 people in the technopolis area, and there should be the possibility of one-day trips to three major metropolitan areas either by air or high-speed train.

According to the industrial plan, a technopolis should consist of three components: an industrial zone, an academic zone, and a residential zone. The industrial zone should have facilities for high-tech industry production, the academic zone should have various research and education facilities, such as private and public research institutes and universities, and the residential zone should have housing for managers, engineers, scientists, and their families [10].

The first phase of the technopolis plan in Japan from 1983 to 1990, measured by manufacturing output, value-added manufacturing, the number of manufacturing employees and population, was considered successful and exceeded the average level of national development. The technopolis plan was officially revised, and the target year for completion was extended from 1990 to 2000 [10].

It should be noted that although technopolis programs can be considered successful in terms of certain indicators of national development, local results may vary significantly. Tables 1 and 2 in the study present some conditions and characteristics of the technopolis depending on the stages of development (from 1983 to 1990 – the first stage, from 1990 to 2000 – the second stage, from 2000 to the present – the modern, third stage), associated with changes in the macroeconomic situation and changes in the approach to the technopolis.

Table 1. Stages of development of the technopolis paradigm. Source: compiled by the authors from [10-12]

First stage (1983-1990)	Second stage (1990-2000)	Third stage (2000-present)
Industrial structural shift from heavy and large-scale Fordist manufacturing to light and small-scale flexible manufacturing systems	Increase in the number of enterprises located abroad, along with the appreciation of the local currency; progress of industrial restructuring	The fourth industrial revolution, the transition from Industry 4.0 to Industry 5.0 based on intelligent cyber-physical and cyber-physical-social systems
The Technology Nation Approach	The development of globalism	Global competitiveness
Financial recovery period	The wave of technological innovation and international competition for the power of technological development	Black Swans, periods of power alternate with protracted crises
Demands to revitalize local economies	Strengthening the foundation of the power of technological development (maturity of the first technopolis period)	Disruptive innovation based on exponential development
Increasing differences in technological capabilities between regions	New information technologies and the spread of informatization	Digitalization and Digital Transformation
Decline of local industry, concentration of high-tech	Promoting a soft economy and a service economy	Human-centeredness Resilience

First stage (1983-1990)	Second stage (1990-2000)	Third stage (2000-present)
industries in large cities, increase in regional inequality	Diversifying and changing Japanese values and consciousness Restoring national financial strength	Intelligent economy

Table 2. Strategies for implementing the technopolis paradigm. Source: compiled by the authors from [10, 11]

First stage (1983-1990)	Second stage (1990-2000)	Third stage (2000-present)
Strengthening the foundation of technological development opportunities	Emphasis on endogenous ways of development	Technological sovereignty
Transfer to high-tech local industry	A preference for individualism	Distributed collaborative forms of cooperation
Identifying local needs and making the most of local supplies	Formation of technopolis networks	Development based on networks, platforms and ecosystems
Technological innovation from the ground up	Adapting to internationalization (open policies, technology transfer, networks)	The Five Innovative Helix
Respect for the independence of human settlements, emphasis on the base of soft technology	Introduction of urban planning	"Smart" megacities

The differences between the three stages of the evolution of the technopolis concept are visible in Tables 1 and 2 above, but the technopolis paradigm still focuses mainly on innovation and economic competition. There are also some technopolises based on specific themes, such as biopolis, digital center, science park, innovation-active cluster [13], and so on.

The main terminological construct of the technopolis concept is the notion of a "technopolis". The word "techno" reflects the emphasis on technology, aimed at renewing the industrial structure to advance the country towards the goal of becoming a "high-tech archipelago" in the 21st century; "polis" is a Greek word meaning a city-state, aimed at developing regions away from leading industrial and cultural centers by accelerating the transfer of technologies to regional industries and reflecting the balance between the public and private sectors. Thus, literally, a technopolis is a territory where high-tech companies, scientific and research centers, incubators and accelerators, as well as infrastructure aimed at supporting innovative activities, are concentrated.

The technopolis concept is developed in different countries of the world and is aimed at creating conditions for the development of an innovative economy and stimulating scientific research and development. Below are several definitions of the concept of a technopolis presented by different companies and associations:

1. "A technopolis is a territory where favorable conditions are created for the development of high technologies, innovations and business" (European Coordination Agency for Research and Development (EUREKA), 1995).

2. "A technopolis is a territory where industrial enterprises, scientific research centers, universities, and incubators coexist and interact, creating favorable conditions for innovation and the development of high-tech companies" (Organization for Economic Cooperation and Development (OECD), 1997).

3. "A technopolis is a territory where ecosystems are created, bringing together enterprises, scientific and research organizations, authorities and other interested parties to stimulate innovative activities and create new jobs" (UNESCO, 2000).

4. "A technopolis is a territory where conditions are created for innovation and the development of high-tech companies, including access to financing, technologies, scientific research and development, as well as qualified personnel" (European Commission, 2007).

5. "A technopolis is a territory where the development of high-tech companies and an innovative economy is based on strong integration of scientific and technological skills and resources, as well as support from authorities and the business community" (National Governors Association, 2012).

A modern technopolis is a city that interactively links technology commercialization with the public and private sectors to stimulate economic development and technology diversification [14]. Regions must maintain a balance between private enterprise profits and public interests. To achieve both of these ideas, the government needs to regulate cooperation between industry, scientists, and local authorities based on the formation of technopolises, without interfering in their activities. Local authorities show their own initiative and try to improve their economic development. The central government only supports efforts to achieve regional deconcentration. In addition, local authorities must create the best conditions for research and production capacities. This leads to strong competition between technopolises [15].

4 Discussion

In addition to the concept of a technopolis, the term "innovation-active cluster" is important in revealing the technopolis concept. In general, an innovation-active cluster is a grouping of companies, scientific and educational organizations, government institutions, and other stakeholders in a specific area aimed at developing an innovative economy and supporting innovation. The main goal of creating an innovation-active cluster is to stimulate the development of high-tech industries and increase their competitiveness in the global market. Within the innovation-active cluster, companies and organizations jointly develop new technologies, produce innovative products and services, exchange experiences and knowledge, and interact with authorities to obtain financial and infrastructure support. For successful operation of the innovation-active cluster, strong leadership, an effective management system, qualified personnel, and access to financing are necessary. Another important factor is the presence of a technological base and scientific research that can be used to develop new products and services.

A.V. Babkin and L.V. Tashenova understand an innovation-active cluster as "a group of economic entities from different spheres of activity united around a single system-forming, strategically significant enterprise based on the principles and methods of a systemic approach, developing, owning, and implementing globally competitive technologies that ensure systemic sectoral and/or intersectoral development, contributing to the achievement of the above-mentioned goals based on existing and implemented digital information platforms, transitioning to new models and forms of doing business and using not individual innovation projects, but their combinations in an effective combination for the economy, including the industry, region, and cluster" [16, 17].

The authors adhere to the conceptual scheme of the "technopolis wheel" [14, 18], which emphasizes the importance of institutions in the academic, business, and government sectors and explains how institutional alliances can determine the strategy and tactics of economic development based on technology (Figure 1).

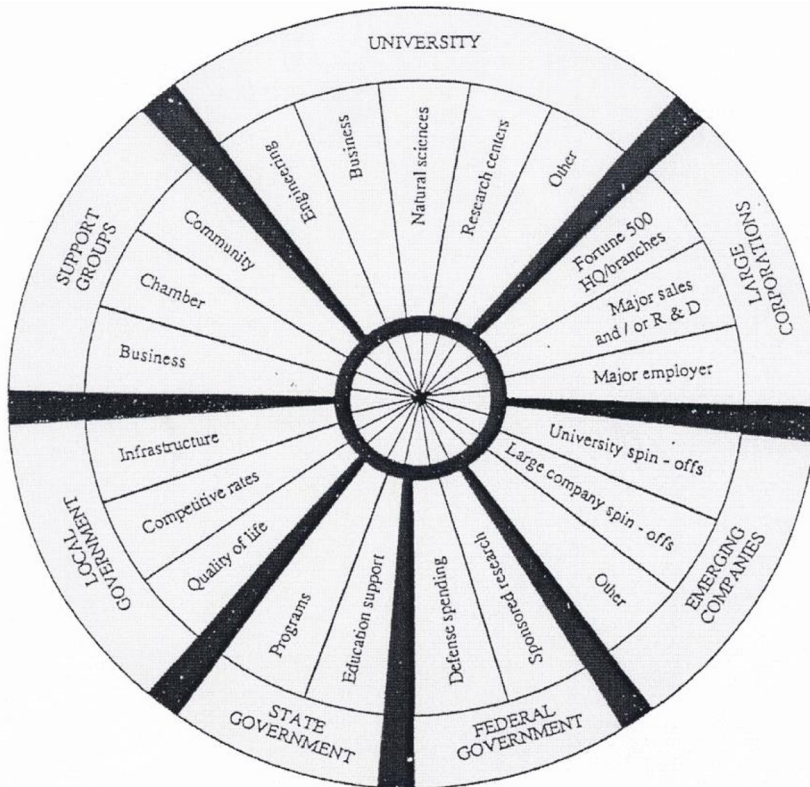


Fig. 1. Conceptual scheme of the technopolis wheel. Source: [14, 18]

The wheel of the technopolis is a conceptual model that describes the main elements interacting in the technopolis and determining its functioning. Each of these elements interacts with other elements, creating an ecosystem that promotes the development of an innovative economy and attracts investments.

The wheel reflects the interaction of seven main segments in the institutional structure of the technopolis: research universities, large technology companies, small technology companies, government, local authorities, federal government, and support groups. And finally, perhaps most importantly, influential individuals – key figures, agents of influence, who connect the seven segments of the wheel.

In a broader sense, the key segments of the technopolis wheel can be operationalized as (1) networks and connectivity, (2) investment capital, and (3) innovation and R&D. For example, companies can collaborate with scientific organizations to develop new technologies, and investors can finance these projects. Educational institutions can prepare personnel for companies, and the government can provide financial and infrastructure support to create favorable conditions for the development of the technopolis.

Four factors are particularly important in the development of the technopolis [14]:

1. Achieving scientific excellence is a process aimed at creating and developing scientific and research centers engaged in the development of new scientific methods and technologies. These centers can work closely with universities and research institutes, allowing for knowledge and experience exchange.

2. Developing and maintaining new technologies for emerging industries is a process aimed at creating technologies that will allow new sectors of the economy to develop. For

example, in recent years, such industries as information technology, biotechnology, energy, and others have become of great importance.

3. Attracting large technology companies is a process aimed at attracting large companies engaged in the development and implementation of new technologies to the technopolis. This creates favorable conditions for the development of high-tech industries and attracting investments.

4. Creating one's own technology companies is a process aimed at creating new companies engaged in the development and implementation of new technologies. These companies can be created as startups or as departments within existing companies.

The development of the technopolis is a complex and multifaceted process that requires the interaction of many factors and parties. However, if all components work together, this can lead to the creation of a strong innovation ecosystem and stimulate economic development as a whole. The formation of an intellectual cyber-physical technopolis and an innovation-active cluster can become an effective tool for ensuring the economic security of depressed areas. Creating such territories allows attracting investments, developing high-tech industries, and creating new jobs, which contributes to improving the economic situation in the region.

5 Conclusion

Based on the analysis of three stages of the evolution of the technopolis paradigm, some factors for successful creation and development of technopolises can be identified [11]:

1. Establishment of partnership relations between universities and research centers with industry and government.

2. Combining small business, large and entrepreneurial clusters in environmental research and development with a multi-profile university education program based on a theme that includes advanced digital technologies, biosciences and biotechnology, advanced materials, environmental technologies, etc.

3. Establishment of intensive partnership based on a five-fold innovation spiral between industry, government, universities, society, and the environment in a community that lives and develops together (the "pedestrian-scale" ecosystem, including based on remote interaction technologies Web 4.0).

4. Creation of advanced technological infrastructure for collaborative networks, digital platforms, and ecosystems.

According to the authors, the concept of the technopolis wheel has important implications for the formation of a system-forming innovation-active cluster to improve the economic security of the region. Thus, the technopolis wheel can be used to study the movement of technological entrepreneurs and the reasons why they join established ecosystems. Institutions and support structures within technopolises connect and support key resources that are central to technological system-forming innovation-active clusters, allowing the entrepreneurial ecosystem to develop [19].

An area for further research could be the expansion of the concept of the technopolis wheel based on additional indicators of institutional structures and alliances of ecosystem interaction.

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