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RESEARCH ARTICLE

Formation and Development of Innovative Infrastructure in The Higher Education System

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Abstract

Currently one of the key drivers of economic growth is innovation and knowledge, which are receiving increasing attention. In this regard, the higher education system is not limited to training qualified specialists but also actively participates in the creation and development of new knowledge. The innovative infrastructure of higher education encompasses a set of institutions, resources, and mechanisms that ensure collaboration between science, education, and industry. The main purpose of this article is to explore the scientific and theoretical foundations of developing innovative infrastructure in higher education and to scientifically substantiate the objective necessity of its advancement.

KEYWORDS

Higher education, innovation, innovative infrastructure, innovative services.

INTRODUCTION

The experience of developed countries demonstrates that achieving sustainable economic growth and development, creating a favorable social environment, and securing a high international standing for a nation require the successful implementation of innovation-driven development processes. In this regard, the sector of fundamental research and scientific development, a high-quality education system—particularly higher education—and a purposeful state policy aimed at improving the regulatory and legal framework governing interactions among participants in the innovation process at all stages play a crucial role in the development of the national innovation system.

Today, significant transformations in the global economy, including geopolitical tensions, trade restrictions, disruptions in logistics chains, and instability in energy markets, are creating new economic challenges for Uzbekistan. The fact that raw materials such as cotton fiber, non-ferrous metals, natural gas, and other resources still constitute a substantial share of the country's export structure, together with the necessity to increase the share of value-added industrial products, makes this issue increasingly important and relevant.

Higher education institutions serve as key centers for the creation, dissemination, and commercialization of knowledge. Therefore, the establishment and continuous development of innovation infrastructure within the higher education system is becoming one of the most important factors in strengthening national competitiveness, accelerating technological progress, and ensuring sustainable socio-economic development. In the context of the ongoing modernization of Uzbekistan's economy and its integration into the global innovation space, enhancing the effectiveness of innovation infrastructure in higher education has become a strategic priority.

METHODS

The study of innovation infrastructure within the higher education system is based on a comprehensive theoretical analysis and a systematic approach. To identify the scientific and theoretical foundations for the formation and development of innovation infrastructure, the research employed the methods of comparative historical analysis, synthesis, induction, and deduction.

This methodology is aimed at identifying existing barriers and developing scientifically grounded recommendations for improving innovation infrastructure in higher education institutions. It reflects the practical nature of the research and its orientation toward the practical application of the achieved results.

RESULTS

It is well known that the first universities emerged as early as the Middle Ages. In particular, the formation of universities in Europe is generally attributed to the late eleventh and early twelfth centuries. The primary function of universities during that period was the education of students. At the beginning of the nineteenth century, A. Humboldt merged the Royal Academy with the University of Berlin, creating an educational institution with two equally important functions: educating students and conducting scientific research [4].

At the beginning of the twentieth century, universities began to be recognized as sources of new knowledge and technologies. Consequently, research activities became an essential function of any university alongside student education. In the literature, this phenomenon is often referred to as the "first academic revolution." Attempts to commercially apply knowledge generated within universities existed as early as the nineteenth century; however, it is only in recent times that such activities have reached the scale of the "second academic revolution." Today, for many higher education institutions, this activity is becoming a necessary condition for their continued existence.

At present, depending on the number and scope of university functions, the terms "University 3.0" and "University 4.0" are also frequently encountered in academic literature [5].

In our view, one of the factors slowing the development of higher education is the insufficient level of public financial support allocated for scientific and research activities. As a result, higher education institutions are compelled to seek alternative sources of revenue to compensate for funding shortages. One such measure is the expansion of fee-based educational services.

Traditionally, higher education institutions (HEIs) have fulfilled two core missions: education and research. However, over recent decades, a "third mission" has emerged as an institutional responsibility—integrating knowledge and technology into the economy through commercialization, entrepreneurship, and regional development. This evolution can be conditionally represented through four stages.

Stage 1. Institutionalization of Intellectual Property (1980s).

The 1980s were characterized by the institutionalization of intellectual property rights, enabling universities to obtain legal ownership and licensing rights over inventions created through government-funded research. For example, in the United States, the Bayh–Dole Act (35 U.S.C. §200–212) was adopted to accelerate the commercialization of research outcomes generated with public funds. Under this legislation, universities were granted the right to claim ownership of inventions resulting from government grants and independently manage patenting and licensing activities. These provisions stimulated university–industry cooperation and standardized the operations of Technology Transfer Offices (TTOs). From this period onward, TTOs began functioning as "one-stop" service centers, introducing invention disclosure procedures, patent landscape analyses, standard agreements such as Material Transfer Agreements (MTAs) and Non-Disclosure Agreements (NDAs), as well as internal revenue-sharing policies. Performance measurement indicators such as invention disclosures, patents, and licensing revenues were also introduced.

Stage 2. Transition to the Triple Helix Model (1990s).

During the 1990s, the adoption of the Triple Helix model led to the platformization of cooperation among universities, industry, and government. Technology parks, business incubators, and joint laboratories were established; framework agreements with industry and consortium-based research projects were launched; and personnel mobility and co-patenting activities increased. Performance assessment during this period relied on indicators such as the volume of contract research and development (R&D), the number of technology park residents, joint publications and patents, and time-to-market metrics.

Stage 3. Entrepreneurial University Model (2000s).

In the 2000s, the concept of the entrepreneurial university became dominant, and innovation was integrated into university strategies and key performance indicators (KPIs). A structured pipeline consisting of pre-incubation, incubation, and acceleration stages was established. Proof-of-Concept (PoC) grants and matching grants were introduced, while industry liaison services were strengthened. Evaluation criteria increasingly focused on the number and sustainability of spin-off companies, PoC conversion rates, the share of business-to-business (B2B) revenue, and the coverage of entrepreneurship education programs.

Stage 4. Open Innovation, Mission-Oriented Policies, and Digitalization (2010–2020s).

Between 2010 and 2020, open innovation, mission-oriented policies, and digital transformation assumed a central role. Through open platforms and consortiums, efforts were directed toward solving "grand challenges." Data infrastructure initiatives based on FAIR principles and Data Management Plans (DMPs), intellectual property management systems, and crowd-based R&D practices became increasingly widespread. Evaluation metrics expanded beyond patents and licensing revenues to include broader knowledge transfer indicators, such as contract research, personnel mobility, public innovation initiatives, and data-sharing activities. Internal benchmarking dashboards further enhanced institutional accountability.

Thus, a continuous evolutionary process can be observed across these stages: from legal certainty, to multi-channel collaboration, to entrepreneurial culture, and ultimately to a platform- and mission-based innovation ecosystem.

Stage 5. Valorization and Mission-Oriented Ecosystems, Open Science, Digitalization, Standardized Spin-Out Practices, and AI-Assisted Technology Transfer (2020s–Present).

The period from the 2020s to the present can be characterized as the era of valorization and mission-oriented ecosystems, open science and digitalization, standardized spin-out practices, and AI-assisted technology transfer.

At the European Union level, the principles of Knowledge Valorisation and the Code of Practice on the Management of Intellectual Assets have been adopted. These initiatives encourage universities to create value not only from patents but also from assets such as data, software, and know-how. Consequently, economic and social impact has become a primary focus within technology transfer policies and key performance indicators (KPIs) [6].

At the same time, assessment reforms promoted by the Coalition for Advancing Research Assessment (CoARA) have encouraged universities to complement traditional publication metrics with broader indicators of holistic impact, including valorization, entrepreneurship, and partnerships [7].

Mission-oriented and regional innovation platforms have also gained momentum. For example, in the United States, the National Science Foundation's (NSF) Regional Innovation Engines Program provides substantial multi-year funding to university–industry–regional consortia, thereby accelerating outcome-oriented research and development (R&D).

The open science movement has expanded significantly as well. The 2022 Memorandum of the Office of Science and Technology Policy (OSTP) requires that the results of federally funded research be made immediately accessible to the public by 2025. This policy has accelerated the implementation of data management practices based on Data Management Plans (DMPs) and FAIR principles (Findable, Accessible, Interoperable, and Reusable), as well as the adoption of open repositories and open licensing models within university policies.

In the field of spin-outs, standardization has increased considerably. The United Kingdom's 2023 Spinout Review and the University Spinout Investment Terms (USIT) Guidelines developed by TenU have contributed to improving transparency in spin-out agreements, particularly for software startups, while aligning university equity shares and contractual conditions with sector-specific requirements [8].

To support these developments with qualified human resources, Deep Tech Talent initiatives, promoted by the European Institute of Innovation and Technology (EIT), have gained widespread recognition. By 2025, the initiative aims to achieve practical outcomes through the participation of one million learners and professionals.

Finally, technology transfer itself is becoming increasingly digitalized. According to the 2024 World Intellectual Property Organization (WIPO) Report, patent activity related to generative artificial intelligence has grown rapidly, and intellectual property management strategies are increasingly incorporating AI-based tools. Within Technology Transfer Offices (TTOs), artificial intelligence is being integrated into processes such as patent landscape analysis, prior-art searches, and contract drafting

Decesion. The development of universities has followed a sequential path from education, to education combined with scientific research, and subsequently to the "third mission" (knowledge valorization). As a result, higher education institutions (HEIs) have become the core of regional innovation ecosystems.

In conclusion, it is advisable to focus on the following aspects in order to promote the development of innovation infrastructure within the higher education system:

1. Integrating a Knowledge Valorization Strategy into the HEI Development Concept

It is advisable to incorporate a dedicated knowledge valorization strategy into the development framework of higher education institutions. This strategy should define three- to five-year objectives, priority sectors and clusters, partnership maps, and a diversified financing mix. Policies governing intellectual property (IP), spin-out regulations, revenue-sharing mechanisms, and conflict-of-interest management procedures should be formally established through an appropriate regulatory framework. Such institutional clarity ensures the predictability and accountability of technology and knowledge transfer processes.

2. Strengthening Technology and Knowledge Transfer Offices (TTOs/KTOs)

Technology Transfer Offices (TTOs) or Knowledge Transfer Offices (KTOs) should operate under a "one-stop-shop" model, standardizing the process pipeline from invention disclosure to patent landscape analysis, intellectual property decision-making, licensing or collaborative development agreements, and post-transfer monitoring. Through industry liaison functions, efficient contracting mechanisms and technical requirement engineering with enterprises can be established. Furthermore, a structured pathway consisting of pre-incubation, incubation (MVP development), and acceleration stages, supported by prototyping laboratories, should be implemented. The expected outcome is an increase in contract research and development (R&D) activities and a higher rate of technology adoption.

3. Diversifying Revenue Sources

To reduce the risks associated with excessive reliance on tuition-based income, revenue streams should be diversified through contract research, consulting services, licensing agreements, spin-out equity participation, and alumni or partner-supported funds. Short-cycle Proof-of-Concept (PoC) mini-grant programs and industry-based matching grant mechanisms should be introduced. In addition, regional consortia should be established to support mission-oriented projects. These measures are expected to increase the proportion of investment-ready technologies and improve market-entry conversion rates.

4. Advancing Digital Infrastructure and AI-Assisted Technology Transfer

Digital repositories that comply with FAIR principles and Data Management Plan (DMP) requirements, together with IP and Customer Relationship Management (CRM) platforms and standardized digital contract templates, should be established. Artificial intelligence-assisted tools for prior-art searches, patent landscape analysis, and contract drafting should be piloted within TTO operations, while maintaining legal expertise as the primary authority in decision-making processes. These initiatives will enhance data governance, transparency, and transfer efficiency while reducing transaction costs.

5. Standardizing Spin-Out and Startup Governance

Sector-specific model terms should be introduced, including differentiated equity and licensing arrangements for software-based and deep-tech ventures. Founder-friendly provisions should be clearly standardized. Potential conflicts of interest, the role of academic supervisors, and the allocation of intellectual ownership rights should be regulated through transparent guidelines. Such measures will improve the transparency of entrepreneurial pathways and enhance startup sustainability.

6. Establishing a Balanced Innovation Performance Scorecard

A balanced scorecard should be implemented that includes indicators related to intellectual property (invention disclosures, patents, licenses, and revenue generation), technology transfer (contract R&D and joint laboratories), entrepreneurship (PoC projects and spin-out survival rates), open science (open-access publications and datasets supported by DMPs), and regional impact. An annual "Innovation Passport" should be published, defining threshold levels for tuition-based income dependence and corresponding social compensation measures. In addition, standards related to knowledge security—including due diligence procedures, export control compliance, and data protection requirements—should be systematically institutionalized. These measures will contribute to institutional sustainability and provide a reliable basis for measuring socio-economic impact.

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