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SPECIFICITIES OF THE FORMATION AND STAGES OF DEVELOPMENT OF IT-SECTOR INNOVATION CLUSTERS IN THE CONTEXT OF MARTIAL LAW

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THE PURPOSE OF THE ARTICLE is to study the peculiarities of formation and stages of development of innovation clusters in the IT sphere under martial law, to identify possible obstacles faced by IT clusters during military conflicts, as well as ways to overcome them.

RESEARCH METHODS. The following special and general scientific methods were used in the article: socio-economic analysis, scenario analysis, SWOT analysis, expert assessments, monitoring and evaluation of results, tabular and graphical, induction and deduction, etc.

PRESENTING MAIN MATERIAL. The development of innovation clusters is one of the key drivers of economic growth in a globally competitive environment. Clusters bring together companies, research institutions and government agencies to jointly develop innovative solutions. Innovation clusters are important elements of the modern economy that stimulate technological progress and economic growth, which are formed on the basis of a concentration of interconnected enterprises, institutions and organisations that interact and support each other. Innovation clusters in the IT sector not only ensure technological progress but also create new economic opportunities. Economic, social, technological, and institutional factors are important factors in the formation and development of innovation clusters. In the context of martial law, when economic stability and access to resources become limited, innovation clusters must adapt to new challenges, ensuring not only development but also the sustainability and security of their members. The war started by Russia in 2022 and the introduction of martial law have dramatically changed the conditions for the development of IT clusters, where the main obstacles are security threats, displacement of personnel, limited access to finance, supply chain disruption, and reduced demand for IT services. Among the main factors influencing the process of forming innovation clusters in the IT sector, economic, social, technological and institutional factors were identified. The formation of innovation clusters in the IT sector includes the following stages: initiation and initial stage; infrastructure creation; development and consolidation; maturity stage and internationalisation. Thus, innovation clusters become a platform for developing products and solutions aimed at supporting government agencies and ensuring public safety. In particular, new approaches to data protection and communications are being developed in the IT sector, programmes are being created to coordinate humanitarian aid, and technologies for monitoring and forecasting crisis situations are being introduced.

CONCLUSIONS. In the context of martial law, innovation clusters face numerous challenges, but at the same time they demonstrate significant adaptability and ability to innovate. The process of formation and stages of development of innovation clusters in the IT sector is characterised by the main steps from initiation to international expansion, and requires the integration of various elements, such as infrastructure, innovation culture and cooperation with educational institutions. The successful formation and development of innovation clusters is critical to stimulating technological progress and increasing competitiveness at the global level, where further research in this area can help identify new approaches and strategies to support and develop innovation ecosystems. The main strategies to ensure the sustainability and further development of IT clusters were identified as the introduction of remote work, diversification of financing, creation of backup infrastructures, search for new markets and close cooperation with government agencies. Thus, martial law can stimulate the development of innovations in certain areas, such as cybersecurity, communications and information security, and IT clusters that are able to adapt to new realities can become key elements of national security and resilience under martial law.

KEYWORDS: innovation clusters; IT-sphere; formation and development; martial law; technological progress; integration; infrastructure; strategy; security; economic stability.

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27	2	1

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ОСОБЛИВОСТІ ФОРМУВАННЯ ТА ЕТАПИ РОЗВИТКУ ІННОВАЦІЙНИХ КЛАСТЕРІВ ІТ-СФЕРИ В КОНТЕКСТІ ВОЄННОГО СТАНУ

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МЕТОЮ СТАТТІ є дослідження особливостей формування та етапів розвитку інноваційних кластерів в ІТ-сфері в умовах воєнного стану, визначення можливих перешкод, з якими стикаються ІТ-кластери під час військових конфліктів, а також шляхів їх подолання.

МЕТОДИ ДОСЛІДЖЕННЯ. В статті було використано такі спеціальні та загальнонаукові методи: соціально-економічного аналізу, сценарний аналіз, SWOT-аналіз, експертні оцінки, моніторинг і оцінка результатів, табличо-графічний, індукції та дедукції, та ін.

ВИКЛАД ОСНОВНОГО МАТЕРІАЛУ. Розвиток інноваційних кластерів є одним із ключових чинників економічного зростання в умовах глобальної конкуренції. Кластери об'єднують компанії, науково-дослідницькі установи та державні органи з метою спільного розвитку інноваційних рішень. Інноваційні кластери є важливими елементами сучасної економіки, що стимулюють технологічний прогрес і економічне зростання, які формуються на основі концентрації взаємозв'язаних підприємств, установ та організацій, що взаємодіють і підтримують один одного. Інноваційні кластери в ІТ-сфері забезпечують не лише технологічний прогрес, але й створюють нові економічні можливості. Важливими чинниками формування і розвитку інноваційних кластерів є економічні, соціальні, технологічні та інституційні чинники. В умовах воєнного стану, коли економічна стабільність та доступ до ресурсів стають обмеженими, інноваційні кластери мають адаптуватися до нових викликів, забезпечуючи не лише розвиток, але й стійкість та безпеку своїх учасників. Війна розпочата Росією у 2022 р. та запровадження воєнного стану кардинально змінили умови розвитку ІТ-кластерів, де основними перешкодами стали загроза безпеці, переміщення кадрів, обмежений доступ до фінансування, порушення ланцюгів постачання та зниження попиту на ІТ-послуги. Серед основних чинників впливу на процес формування інноваційних кластерів в ІТ-сфері було виокремлено економічні, соціальні, технологічні та інституційні чинники. Формування інноваційних кластерів ІТ-сфери включає такі етапи: ініціація та початковий етап; створення інфраструктури; розвиток і консолідація; етап зрілості та інтернаціоналізація. Отже, інноваційні кластери стають платформою для розробки продуктів і рішень, які спрямовані на підтримку державних структур та забезпечення безпеки населення. Зокрема, в ІТ-сфері розвиваються нові підходи до захисту даних та комунікацій, створюються програми для координації гуманітарної допомоги, а також впроваджуються технології моніторингу та прогнозування кризових ситуацій.

ВИСНОВКИ. В умовах воєнного стану інноваційні кластери стикаються з численними викликами, але водночас вони демонструють значну адаптивність та здатність до інновацій. Процес формування та етапи розвитку інноваційних кластерів в ІТ-сфері характеризується основними кроками від ініціації до міжнародної експансії, і вимагає інтеграції різних елементів, таких як інфраструктура, інноваційна культура та співпраця з освітніми установами. Успішне формування та розвиток інноваційних кластерів є критичним для стимулювання технологічного прогресу та підвищення конкурентоспроможності на глобальному рівні, де подальші дослідження в цій сфері можуть допомогти виявити нові підходи та стратегії для підтримки і розвитку інноваційних екосистем. Основними стратегіями для забезпечення стійкості та подальшого розвитку ІТ-кластерів було визначено впровадження віддаленої роботи, диверсифікація фінансування, створення резервних інфраструктур, пошук нових ринків збуту та тісну співпрацю з державними органами. Отже, воєнний стан може стимулювати розвиток інновацій у певних сферах, таких як кібербезпека, комунікації та інформаційна безпека, причому ІТ-кластери, здатні адаптуватися до нових реалій і можуть стати ключовими елементами національної безпеки та стійкості в умовах воєнного стану.

КЛЮЧОВІ СЛОВА: інноваційні кластери; ІТ-сфера; формування та розвиток; воєнний стан; технологічний прогрес; інтеграція; інфраструктура; стратегія; безпека; економічна стабільність.

Statement of the problem. The development of innovation clusters has become one of the key drivers of economic growth in a globally competitive environment. Clusters bring together companies, research institutions and government agencies to jointly develop innovative solutions. This topic is particularly relevant in the IT sector, which has become a driving force behind the digital transformation of various sectors of the economy. Innovation clusters are also important elements of the modern economy, driving technological progress and economic growth. They are formed based on a concentration of interconnected enterprises, institutions and organisations that interact and support each other. In the IT sector, which is characterised by rapid development and a high level of innovation, clusters play a particularly important role due to the need for highly skilled personnel, investment in research and development, and rapid adaptation to changing technological trends. Innovation clusters in the IT sector not only drive technological progress but also create new economic opportunities. Clusters are geographically concentrated networks of businesses that interact with each other and with research institutions to stimulate innovation and increase competitiveness. Economic, social, technological, and institutional factors are important factors in the formation and development of such clusters. In the context of martial law, when economic stability and access to resources are limited, innovation clusters must adapt to new challenges, ensuring not only development but also the sustainability and security of their members.

Analysis of publications on the problem. The main aspects of the formation, development and stages of building innovative clusters in the IT sector are within the circle of scientific interests of such scientists: N. Abashkina, Yu. Nikolaiev, V. Andreieva, A. Bezus, N. Sychova, K. Shafranova, P. Bubenko, N. Dril, Ye. Buriak, P. Puzyrova, R. Hanushchak, I. Hnatenko, Ye. Snitko, R. Markov, V. Utkin, S. Kudyn, K. Lavrukhina, V. Melnykov, O. Nechyporenko, Yu. Nosenko, L. Sinelnyk, O. Olshanska, I. Tkachenko, A. Omelianska, A. Tolstova, V. Utkin, Z. Yanchenko, B. Yukhnov, D. Korsakov, Ya. Yukhman, Yu. Zaloznova, M. Soldak, Z. Zhyvko, I. Raikovska, O. Kovtun, L. Kurhuzenkova and others. However, the issue of martial law has not been studied to the fullest extent.

Statement of the main results. An innovation cluster can be defined as a geographically concentrated group of interconnected companies, suppliers, government agencies and other organisations that collaborate to create innovative products and services. Innovation clusters facilitate the exchange of knowledge, the creation of joint projects, and the improvement of the competitiveness of individual companies as well as entire regions or countries. Clusters play a special role in the IT sector, as this industry is driving digital innovation. Interaction between IT companies, start-ups, research institutions and governments creates a synergistic effect that fuels the rapid development of

new technologies such as artificial intelligence, big data, blockchain, etc. The key factors for the successful functioning of IT clusters are the availability of skilled personnel, access to finance, infrastructure development, and cooperation between cluster members. In a stable environment, these factors ensure the dynamic development of innovation clusters, but during martial law, they acquire new features as numerous barriers to their development arise (Abashkina and Nikolaiev, 2021; Nechyporenko, Nosenko and Sinelnyk, 2021; Puzyrova, 2019; Bezus, Sychova and Shafranova, 2019; Bubenko and Dril, 2023; Andreieva, 2015; Sadovskyi and Volodchenkov, 2024; Buriak, 2019).

The war started by Russia in 2022 and the introduction of martial law dramatically change the conditions for the development of IT clusters. Thus, the key obstacles for IT clusters under martial law are as follows (Table 1).

Table 1

Key obstacles for IT clusters under martial law

№	Type	Signs.
1	Threat to security	Hostilities pose a direct threat to the physical security of employees and infrastructure. The risk of destruction of production facilities, loss of information resources, limited access to energy resources and instability of communication networks – all these factors negatively affect the work of IT companies.
2	Displacement of staff	During military operations, skilled personnel may be forced to leave the region, which creates significant challenges for the retention and development of human capital. For many companies, attracting new staff becomes difficult due to internal migration or emigration of specialists.
3	Limited access to finance	Investments in wartime become less affordable due to increased risks. Many investors are refusing to invest in regions with an increased security threat, which significantly reduces financial resources for the development of innovative projects.
4	Supply chain disruption	Under martial law, supply chains can be severely disrupted by border closures, blockades of transport routes, and destruction of logistics facilities. This leads to delays in the supply of necessary equipment and materials for IT clusters.
5	Decreased demand for IT services	During martial law, the country's economy may experience a significant decline, which affects the demand for IT products and services. Companies may lose customers or face delays in payments, leading to financial difficulties.

Source: built by the authors on the basis of (Abashkina and Nikolaiev, 2021; Nechyporenko, Nosenko and Sinelnyk, 2021; Puzyrova, 2019; Bezus, Sychova and Shafranova, 2019; Bubenko and Dril, 2023; Andreieva, 2015; Sadovskyi and Volodchenkov, 2024; Buriak, 2019).

Among the main factors influencing the process of formation of innovation clusters in the IT sector are economic, social, technological and institutional.

Economic factors are critical for the formation of innovation clusters and consist of the following derivatives:

– financing – the availability of affordable financial resources, both from the state and private investors, is the basis for the development of start-ups and new technologies. Investments in research and development (R&D) contribute to the creation of innovative products and services;

– costs of innovation – high costs of innovation can be both a barrier and an incentive for cluster formation. Economic incentives to invest in innovation and research contribute to the development of new technologies and competitiveness;

– competition and co-operation – the level of competition and opportunities for co-operation between firms within a cluster are important factors. Competition can stimulate innovation, while cooperation can facilitate the exchange of knowledge and resources.

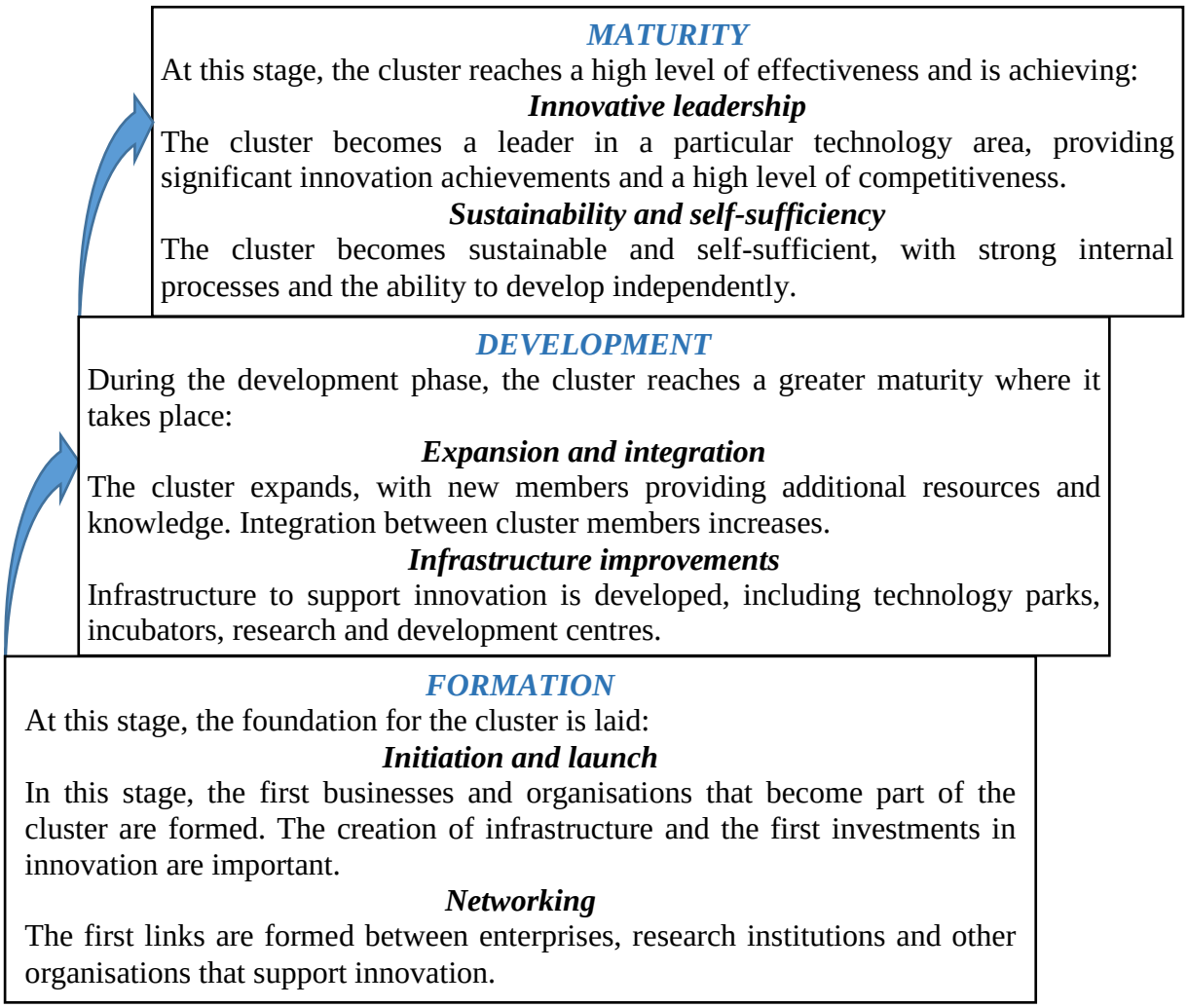
Among the social factors, the most important are skilled labour (availability of highly skilled IT professionals is an important factor for cluster development; educational institutions and training programmes that prepare personnel for the innovation sector support cluster formation); culture of innovation (a social culture that supports innovation, risk-taking and entrepreneurial spirit is an essential factor for cluster formation; a culture that promotes the adoption of new ideas and approaches promotes innovation).

Technological factors that form the infrastructure for the development of innovation clusters include technological and innovation infrastructure: technological infrastructure – implies the availability of a developed technological infrastructure, such as high-speed Internet connections and modern computer networks, which is critical for the development of IT clusters; innovation infrastructure – implies innovation centres, technology parks, laboratories, accelerators and incubators that provide the necessary resources for the development of new technologies and support for old ones.

Institutional factors define the basis for the formation and development of clusters, namely: policy and regulation (government policy aimed at supporting innovation initiatives and creating a favourable business environment is a key factor for the formation of clusters); legislative initiatives (legislative initiatives that protect intellectual property and promote innovation are important for stimulating innovation) (Dovbush and Puzyrova, 2020; Puzyrova and Sadovskyi, 2024; Hanushchak, 2024; Hnatenko, Snitko, Markov and Utkin, 2021; Kudyn, 2023; Puzyrova and Sadovskyi, 2023).

The stages of innovation cluster development are shown in Fig. 1. The formation of innovation clusters in the IT sector is a complex and multifaceted process that includes several key stages:

1. Initiation and initial stage. The process of forming an innovation cluster begins with the emergence of an idea or concept that unites the interests of various participants. At this stage, it is important to identify the potential for creating a cluster, assess market needs, and identify key players such as businesses, universities, research institutions, and investors. The main task is to create a platform for the exchange of ideas and resources.



Source: built by the authors on the basis of (Dovbush and Puzyrova, 2020; Puzyrova and Sadovskyi, 2024; Hanushchak, 2024; Hnatenko, Snitko, Markov and Utkin, 2021; Kudyn, 2023; Puzyrova and Sadovskyi, 2023).

Fig. **1. Stages of development of innovation clusters in the economy**

2. Creation of infrastructure. The second stage involves the creation of the necessary infrastructure that provides the physical and organisational basis for

the cluster to function, which may include technology parks, research laboratories, start-up incubators, and the development of innovation support policies. It is important to ensure access to the necessary resources and create conditions for active interaction between participants.

3. Development and consolidation. At this stage, the cluster begins to function in the mode of active interaction between the participants. Businesses, research institutes and other organisations work on joint projects, which contributes to the development of new technologies and business models. It is important to ensure the cluster's sustainability and adaptability, as well as to attract new members to expand its capabilities.

4. Maturity and internationalisation. In the last stage, the cluster reaches maturity and begins to interact with international markets. This may include expanding beyond national borders, participating in international projects, and attracting foreign investment. Mature clusters become globally competitive and can influence the development of the international innovation ecosystem.

Innovation clusters in the IT sector go through specific stages of development that may differ from other industries:

1. Formation of a critical mass. At the initial stages of IT cluster development, it is important to reach a critical mass of participants to ensure effective interaction and create a favourable environment for innovation. This may include start-ups, large technology companies, universities and research institutes.

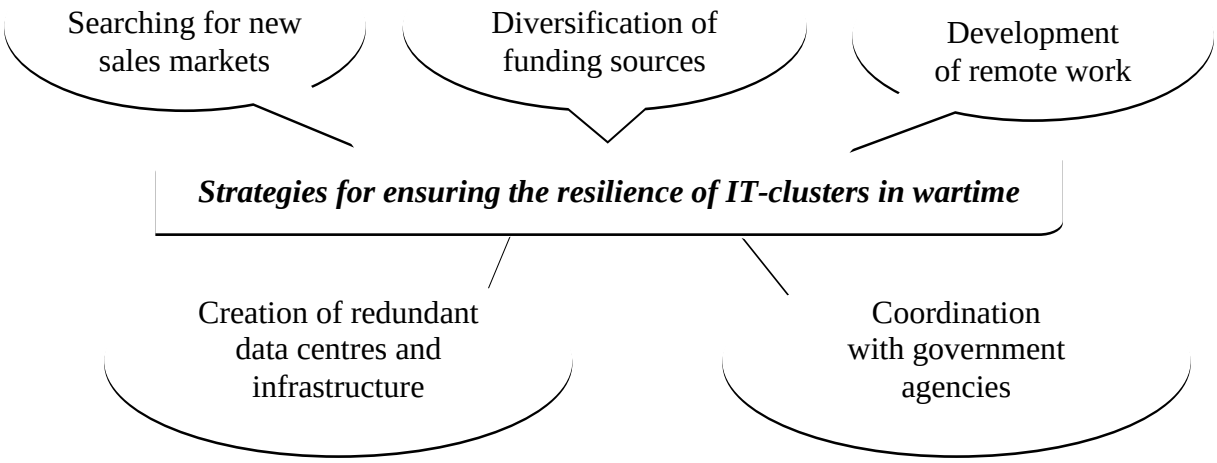
2. Cooperation with educational institutions. Since the IT sector requires highly qualified specialists, close cooperation with educational institutions is an important stage in the development of the cluster, including the creation of internship programmes, joint research, and the involvement of students in real projects.

3. Innovative culture and ecosystem. A successful IT cluster is formed through the development of an innovative culture that promotes the active exchange of ideas and experience. It is important to create an environment that supports risky innovation projects, fosters entrepreneurship, and provides access to finance.

Despite numerous challenges, innovation clusters in the IT sector demonstrate the ability to adapt even under martial law. The main strategies for ensuring the sustainability of IT clusters are as follows (Fig. 2).

Therefore, by switching to remote work, IT clusters can significantly reduce their dependence on physical infrastructure and ensure the safety of their employees. Remote work also allows them to attract specialists from different regions and countries, reducing the risk of losing human capital. To reduce dependence on traditional investors, companies within clusters can turn to alternative sources of funding, such as grants from international organisations,

crowdfunding, or cooperation with venture capital funds specialising in high-risk investments. To ensure the resilience of IT companies during the war, it is important to set up backup data centres in safe regions to minimise the risks of information loss and business continuity. With the shrinking domestic market, IT companies can expand their operations to international markets by using existing contacts with foreign partners and attracting new customers from abroad. In the context of martial law, close cooperation between innovation clusters and government agencies becomes important, particularly in terms of security, tax benefits and startup support. Joint programmes can also be created to ensure infrastructure resilience and help companies in times of crisis (Lavrukhina, 2023; Melnykov, 2021; Olshanska and Puzyrova, 2021; Onofriichuk, 2023; Puzyrova, 2021; Sadovskyi and Puzyrova, 2024; Tkachenko, Puzurova and Omelianska, 2020).



Source: built by the authors on the basis of (Zakharchenko and Alieksieichuk, 2019; Zaiats and Puzyrova, 2021; Kramarenko, 2019; Krakhmalova and Puzyrova, 2020).

Fig. 2. **Strategies for ensuring the resilience of IT clusters in wartime**

Despite all the negative consequences of martial law, it can also stimulate innovation in certain areas. Military conflicts tend to foster the development of new technologies in areas such as cybersecurity, military technology, communications and information security. Thus, innovation clusters can become a platform for the development of products and solutions aimed at supporting government structures and ensuring the security of the population. In particular, new approaches to data protection and communications are being developed in the IT sector, programmes are being created to coordinate humanitarian aid, and technologies for monitoring and forecasting crisis situations are being introduced (Tolstova, 2017; Utkin, 2022; Yanchenko, 2017; Yukhnov, Korsakov, Yukhman, 2021; Zaloznova, Soldak, 2021; Zhyvko, Raikovska, Kovtun, Kurhuzenkova, 2023).

Conclusions. Innovation clusters in the IT sector play a key role in the development of technology and the economy as a whole. In the context of martial law, innovation clusters face numerous challenges, but at the same time, they demonstrate considerable adaptability and ability to innovate. The process of formation and stages of development of innovation clusters in the IT sector covers the main steps from initiation to international expansion, and requires the integration of various elements, such as infrastructure, innovation culture and cooperation with educational institutions. The successful formation and development of innovation clusters is critical to stimulating technological progress and increasing competitiveness at the global level, where further research in this area can help identify new approaches and strategies to support and develop innovation ecosystems. The main strategies to ensure the sustainability and further development of IT clusters are the introduction of remote work, diversification of financing, creation of backup infrastructures, search for new markets and close cooperation with government agencies. Martial law can also stimulate innovation in certain areas, such as cybersecurity, communications and information security, where IT clusters that are able to adapt to new realities can become key elements of national security and resilience under martial law.

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