INTELLECTUAL BUSINESS IN THE RAILWAY SPHERE: FOREIGN CASE STUDIES OF IT STARTUPS

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In the study, foreign case studies of IT startups in the railway sector—as a component of intellectual business—were examined, and the ways in which their experience may be applied to the modernization of Ukrzaliznytsia under wartime conditions were identified. The analysis demonstrated that international practices—such as AI-based predictive maintenance, autonomous inspection systems, digital workflow platforms, and advanced communication technologies—can significantly strengthen the operational efficiency, resilience, and safety of Ukraine's railway system.

A SWOT analysis of creating IT startups in Ukrzaliznytsia was conducted, and key strengths (high demand for modernization, strong national IT talent pool, governmental and international support), weaknesses (institutional resistance, limited funding, regulatory complexity), opportunities (post-war reconstruction, EU integration, new digital business models), and threats (economic instability, cybersecurity risks, talent drain) were identified.

Based on the conducted research, we proposed a Strategic Framework for forming an IT startup ecosystem in Ukrzaliznytsia, consisting of six interrelated directions: establishing a Railway Innovation Hub, strengthening public-private partnerships, implementing regulatory sandboxes, deepening university–industry collaboration, providing secure access to operational data, and introducing innovation-oriented procurement mechanisms. Together, these directions represent a structured approach to stimulating digital transformation, encouraging experimentation, and integrating advanced technological solutions into the railway system.

Prospects for further research involve creating a detailed implementation roadmap for this startup ecosystem, developing evaluation metrics for innovation projects, and examining cybersecurity models tailored to critical railway infrastructure. Future studies should also

consider mechanisms for long-term cooperation between Ukrzaliznytsia and international innovation networks to ensure sustainable technological development.

Key words: intellectual business, railway startups, digitalization, Ukrzaliznytsia, strategic framework, IT startup ecosystem.

ІНТЕЛЕКТУАЛЬНИЙ БІЗНЕС У ЗАЛІЗНИЧНІЙ СФЕРІ: ЗАРУБІЖНІ КЕЙСИ ІТ СТАРТАПІВ

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У статті розглянуто зарубіжні тематичні дослідження ІТ-стартапів у залізничному секторі як складової інтелектуального бізнесу, а також визначено способи застосування їхнього досвіду до модернізації Укрзалізниці в умовах воєнного часу. Аналіз продемонстрував, що міжнародні практики, такі як прогнозне обслуговування на основі штучного інтелекту, автономні системи інспекції, платформи цифрових робочих процесів та передові комунікаційні технології, можуть значно підвищити операційну ефективність, стійкість та безпеку залізничної системи України.

Виконано SWOT-аналіз створення ІТ-стартапів в Укрзалізниці, що дозволило визначити ключові сильні сторони (високий попит на модернізацію, сильний національний резерв ІТ-талантів, урядова та міжнародна підтримка), слабкі сторони (інституційний опір, обмежене фінансування, складність регулювання), можливості (післявоєнна відбудова, інтеграція з ЄС, нові цифрові бізнес-моделі) та загрози (економічна нестабільність, ризики кібербезпеки, відтік талантів).

На основі проведеного дослідження нами запропоновано Стратегічну рамку для формування екосистеми ІТ-стартапів в Укрзалізниці, що складається з шести взаємопов'язаних напрямків: створення Залізничного інноваційного хабу, зміцнення державно-приватного партнерства, впровадження Regulatory sandboxes, поглиблення співпраці між університетами та промисловістю, забезпечення безпечного доступу до операційних даних та впровадження інноваційно-орієнтованих механізмів закупівель. Разом ці напрямки представляють структурований підхід до стимулювання цифрової трансформації, заохочення експериментів та інтеграції передових технологічних рішень у залізничну систему.

Перспективи подальших досліджень включають створення детальної дорожньої карти впровадження запропонованої екосистеми стартапів, розроблення метрик оцінки інноваційних проєктів та вивчення моделей кібербезпеки, адаптованих до критичної залізничної інфраструктури.

Ключові слова: інтелектуальний бізнес, залізничні стартапи, цифровізація, Укрзалізниця, стратегічна рамка, екосистема ІТ-стартапів.

Introduction. Since the onset of Russia's full-scale invasion in 2022, Ukrainian Railways (Ukrzaliznytsia) has emerged as a critical component of the nation's infrastructure, directly contributing to Ukraine's economic sustainability, territorial cohesion, and humanitarian resilience. In the absence of functioning civil aviation and the increased volatility of road transport due to military threats, the railway network has assumed a central role in ensuring national mobility. Ukrzaliznytsia has not only facilitated the large-scale evacuation of civilians from combat zones but has also maintained the uninterrupted delivery of humanitarian aid, military logistics, and medical supplies across the country.

Moreover, the railway system has continued to support the Ukrainian economy through the export of agricultural products,

particularly grain, which is vital not only for Ukraine's economy but also for mitigating global food insecurity. In this context, Ukrzaliznytsia serves as a key logistical backbone for both national recovery and international stability.

Despite operating under wartime conditions, which include regular missile and drone strikes on transport infrastructure, Ukrzaliznytsia has sustained operations with remarkable resilience. Official data indicate that more than 500 kilometers of rail lines and at least 126 stations have been significantly damaged since the beginning of the invasion [1]. Nevertheless, services continue with only limited disruption — underscoring the sector's operational adaptability and strategic relevance.

Given this context, restoring and modernizing Ukrzaliznytsia is not merely a matter of infrastructure rehabilitation but a prerequisite for Ukraine's survival and post-war reconstruction. It is essential to strengthen its digital, logistical, and security capacities through innovation. Investing in railway-based startups and adopting international best practices could play a transformative role in ensuring that Ukrzaliznytsia continues to serve as a pillar of national resilience during and after the conflict.

Additionally, Ukrzaliznytsia's ongoing challenges—such as cyberattacks, outdated infrastructure, and limited integration with European rail systems—highlight the urgent need for digital innovation. The 2018 Shift2Rail report [2] underscores that digital transformation is essential for enhancing efficiency, safety, and customer satisfaction in railways. By fostering IT startups, Ukraine can develop tailored solutions like predictive maintenance, automated logistics, and real-time tracking systems. Such innovations can address systemic inefficiencies and bolster resilience. Ukraine's burgeoning tech ecosystem, supported by initiatives like Diia.City and the Ukrainian Startup Fund, provides a fertile ground for these developments. Integrating IT startups into Ukrzaliznytsia's operations not only

modernizes the railway sector but also contributes to the broader economic recovery and positions Ukraine as a leader in rail innovation.

Intellectual business includes Information and Telecommunication, Financial and Insurance activities, Professional, Scientific and Technical activities, Education, and some other types of activities [3]. Therefore IT sphere definitely belongs to intellectual business.

Analysis of recent studies. *Domestic* scientists who have been covering the topic of startup development in recent years are: Boyarynova K. O. [4], Duma O. I., Zavtura K. O. [5], Kokhan M. O., Mazur A. V. [6], Kravchenko M. O., Gazaryan E. A. [7], V.P. Makoviy [8], Sak T. V., Shostak L. V., Voznyuk Yu. S. [9], Sytnyk N. I. [10], Yatskevich I. V., Petrashevska A. D., Kemarska T. G. [11] and others. Thus, the article by V.P. Makoviy [8] is devoted to the study of the legal nature of a startup as a participant in IT relations in view of the existing scientific approaches, the economic essence of this concept and the provisions of current legislation. In the paper [9] Sak T. V., Shostak L. V., Voznyuk Yu. S. investigated the theoretical aspects of the functioning of startups as a form of innovative business organization: the essence, content, and differences of startups from traditional entrepreneurship were considered.

The issue of digitalization of the railway transport has been studied by Ukrainian researchers V.L. Dykan, H.V. Obruch, [12, 13], V.V. Kompaniets [14], I.V. Tokmakova [15] and others, whose studies outlined the prospects for the development of railway transport enterprises (for instance, in [16]). At the same time, the issues of promoting digitalization with limited investment during the war remained insufficiently researched, which is why in the paper [17] we suggested using experience of Indian Railways with startups developing as a way of enhancing digitalization in railway transport. In [18] we outlined key digitalization priorities for Ukrzaliznytsia, aligning with the Vienna

Declaration by the Community of European Railway and Infrastructure Companies [19]. The study analyzes the current state across five areas: Smart technical operations, infrastructure, freight/passenger transport, ticketing, and human resources.

Unexplored aspects of the issue. Despite the existence of numerous publications devoted to Ukrainian startups, the digitalisation of the national railway sector, and intellectual business, the development of startups within the railway sphere remains insufficiently explored.

The purpose of the study is to analyze foreign case studies of IT startups in the railway sector as a component of intellectual business, to identify ways in which their experience can be applied to the modernization of Ukrzaliznytsia under wartime conditions, and to develop a Strategic Framework for forming an IT startup ecosystem within the Ukrainian railway sector based on the results of SWOT analysis and global best practices.

Main body of the study. In 2018, Ukrzaliznytsia, in cooperation with the 1991 Open Data Incubator, launched the Future of Mobility Lab. UZ edition, an incubation program aimed at implementing innovations in the railway sector. Out of more than 60 submitted applications, 10 startups were selected to participate in a three-month acceleration program. These included projects offering solutions for theft prevention using drones, improved ticket refund systems, and food delivery to train cars [20].

In 2018, Ukrzaliznytsia launched a new business incubator to support startups aiming to modernize Ukraine's railway sector. The initiative was designed to attract innovative solutions in logistics, digitalization, and passenger services, strengthening collaboration between the railway and the tech community [21].

However, according to available information, the further fate of these startups after the conclusion of the incubation program remains unclear. In February 2019, a representative of Ukrzaliznytsia announced that the company planned to select 4–5 projects for further implementation [22]. Yet, no public reports or follow-up news have emerged confirming the actual integration of these initiatives into Ukrzaliznytsia's operations.

This indicates that despite the promising nature of the program and the active involvement of startups, the integration of innovation into state enterprises like Ukrzaliznytsia faces significant obstacles. For such initiatives to succeed, systemic support, transparency, and effective communication between startups and government institutions are essential.

Therefore, examining foreign railway startup initiatives is justified, as their experience can serve as a valuable basis for adapting and implementing innovative solutions within the operational context of Ukrzaliznytsia.

Foreign case studies of IT startups in the railway sector and the proposed ways in which Ukrzaliznytsia may apply their experience are given in the Table 1.

Table 1

Foreign IT railway startup cases and ways Ukrzaliznytsia can apply their experience

Foreign IT railway startup cases	Ways of application IT startups experience by Ukrzaliznytsia
1	2
The German startup *Rail-Flow* [20] offers a digital platform that fully automates and standardizes document flow for freight transportation, enabling users to submit requests, analyze data, and complete transactions within a unified system.	*Digitalize Freight Documentation and Transaction Processes* Ukrzaliznytsia can adopt similar workflow digitalization tools to streamline freight operations, reduce manual processing, minimize errors, and accelerate service delivery.

Fortsetzung von Tabelle 1

1	2
The Indian company *Pantherun Technologies* [20] develops advanced communication solutions based on field-programmable gate arrays (FPGAs), allowing for more compact, flexible, and efficient equipment.	*Modernize On-Board and Stationary Communication Systems* By integrating FPGA-based communication technologies, Ukrzaliznytsia can enhance the reliability of train-to-infrastructure communication, improve data transmission speed, and support the deployment of next-generation signaling and monitoring systems.
International startups like *AXO Track* and *RAILwAI* [21, 22] utilize AI-driven predictive maintenance to proactively identify infrastructure issues, reducing downtime and maintenance costs.	*Leverage Predictive Maintenance and AI Technologies* Ukrzaliznytsia can adopt similar technologies to monitor track conditions and rolling stock health, enhancing operational efficiency and safety.
Startups such as *Next Generation Robotics* [21] have developed autonomous rail inspection robots equipped with LiDAR and optical sensors for detailed infrastructure assessments.	*Implement Autonomous Inspection Systems* Integrating such autonomous systems can aid Ukrzaliznytsia in conducting efficient and accurate inspections, especially in hard-to-reach areas.
Tools developed by startups like *Telegraph* [21, 22] streamline freight rail workflow management.	*Enhance Freight Operations with Workflow Management Tools* By adopting such platforms, Ukrzaliznytsia can optimize cargo operations, improve scheduling, and enhance overall logistics efficiency.
International startup *KONUX* [23] employs a blend of smart sensors, IIoT devices, and AI analytics to continuously monitor the condition of critical railway components — especially switches, crossings, and trackbeds — and to predict failures before they occur.	*Leverage Predictive Maintenance and AI-Driven Infrastructure Monitoring* By adopting a similar predictive maintenance system, Ukrzaliznytsia could optimize its maintenance scheduling, extend the service life of rail infrastructure, reduce unplanned disruptions, and lower long-term maintenance costs.
Rail Vision [24] offers advanced computer-vision and AI-based obstacle detection systems that use sensors and deep-learning to identify hazards on or near the tracks — including people, vehicles, animals, and other objects — giving real-time visual and acoustic alerts intended to prevent accidents and ensure safer operations.	*Enhance Safety Through AI-Based Vision and Obstacle Detection Systems* Implementing such vision-based safety systems within Ukrzaliznytsia could dramatically improve situational awareness for train crews, reduce collision risk, improve safety for passengers and staff, and support more reliable and secure railway operations.
In Indonesia, PT Kereta Api Indonesia [25] modernized a 7,000-km national rail network using an AI-driven predictive maintenance platform (built with sensor data, inspection data, GIS and asset analytics) — achieving up to 40 % improvement in maintenance efficiency and significantly reducing time required per maintenance segment.	*Large-Scale AI-Driven Predictive Maintenance* For Ukrzaliznytsia, this demonstrates the feasibility of deploying predictive maintenance across a national-scale rail network. Deploying similar analytics and data-integration platforms could reduce maintenance overhead, lower operational costs, and increase system reliability — especially important for long-distance and high-traffic routes.

Additionally, engaging with European initiatives such as EU-Rail can provide Ukrzaliznytsia with access to funding, research collaborations, and a broad innovation ecosystem — facilitating the development and implementation of cutting-edge railway technologies. As the successor to Shift2Rail, EU-Rail continues and expands its predecessor's mission to accelerate rail research and innovation across Europe. By integrating global innovations supported by EU-Rail — including digital automation,

system interoperability, and advanced infrastructure technologies — Ukrzaliznytsia can accelerate its digital transformation, improve service quality, and strengthen its position as a modern, efficient railway operator aligned with European standards.

To understand how these opportunities can be effectively leveraged within the Ukrainian context, it is essential to examine the strategic environment in which such innovations would be implemented. Therefore, a comprehensive assessment of Ukrzaliznytsia's internal capabilities and external conditions is required. SWOT analysis of creating IT startups within Ukrzaliznytsia is presented in Fig. 1.
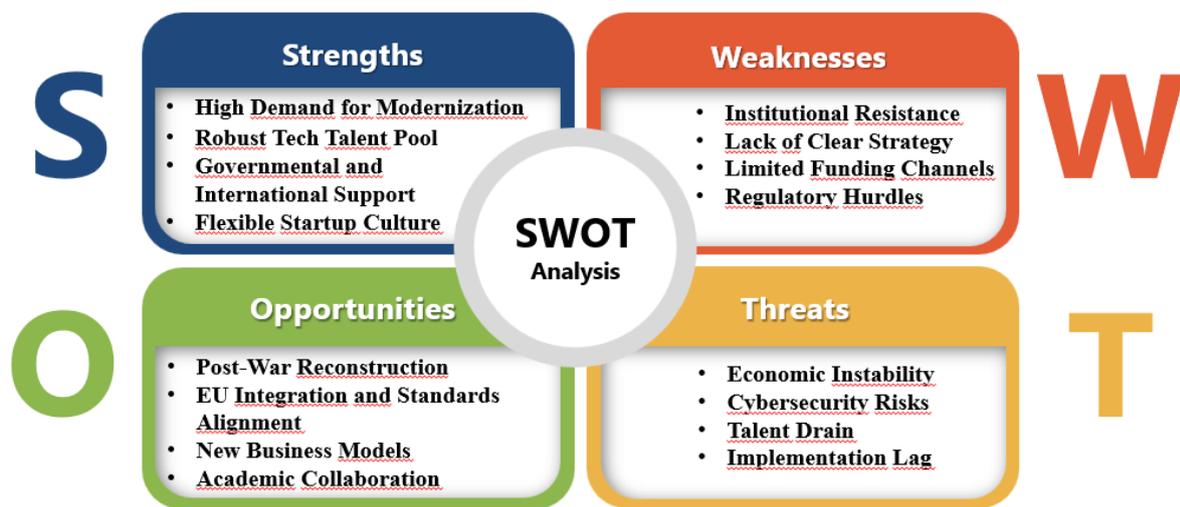
Main strengths are:

- High Demand for Modernization: The outdated state of Ukraine's railway infrastructure creates immediate demand for digital innovation;

- Robust Tech Talent Pool: Ukraine's IT sector is well-developed, offering skilled professionals ready to create scalable solutions;

- Governmental and International Support: Initiatives like Diia.City and EU programs (e.g., Shift2Rail) provide a supportive ecosystem;

- Flexible Startup Culture: Startups bring agility, making it easier to implement niche and experimental technologies quickly.

Fig.1. SWOT analysis of creating IT startups in Ukrzaliznytsia
(created by the author)

Main weaknesses are:

- Institutional Resistance: Corruption and managerial reluctance impede rapid adoption of startup solutions;

- Lack of Clear Strategy: Absence of a national digitalization roadmap or centralized coordination body within Ukrzaliznytsia;

- Limited Funding Channels: Access to consistent venture capital or public grants remains fragmented;

- Regulatory Hurdles: Navigating railway safety standards and bureaucratic processes can delay or deter innovation.

Main opportunities are:

- Post-War Reconstruction: The rebuilding phase offers a unique chance to modernize using digital tools from the outset;

- EU Integration and Standards Alignment: Alignment with EU rail standards opens new markets and collaboration channels;

- New Business Models: Data-driven services, AI-based maintenance, and customer-centered platforms can be monetized;

- Academic Collaboration: Ukrainian universities are increasingly active in digital R&D and can act as innovation partners.

Main threats are:

- Economic Instability: War

conditions and inflation can limit investment in non-essential innovation;

- Cybersecurity Risks: As digital reliance increases, so does vulnerability to cyberattacks;

- Talent Drain: Skilled professionals may emigrate or prefer private tech firms over public rail projects;

- Implementation Lag: Even successful pilots may struggle to scale due to institutional inertia or regional disparities.

Ukraine's extensive railway network, combined with outdated infrastructure, limited digital integration, and the pressure of wartime logistics, creates an urgent need for innovative, adaptive solutions. IT startups can help bridge technological gaps, address inefficiencies, and provide tailored digital tools for resilience and modernization. Moreover, Ukraine's robust tech talent pool, supported by initiatives like Diia.City and the Ukrainian Startup Fund, provides fertile ground for transport-oriented entrepreneurship.

The SWOT analysis reveals that Ukrzaliznytsia possesses strong technological potential and favourable external conditions for IT startup development, yet faces institutional, financial, and regulatory constraints. Leveraging its opportunities while mitigating identified threats requires a structured, innovation-oriented approach. These insights form the basis for developing targeted strategy to foster IT startups within Ukrzaliznytsia.

We propose a Strategic Framework for Developing an IT Startup Ecosystem within Ukrzaliznytsia that includes six strategic directions aimed at fostering sustainable IT-based innovation.

1. Comprehensive strategy for developing an IT startup ecosystem within Ukrzaliznytsia begins with the establishment of a dedicated *Railway Innovation Hub*. Such a unit—created either inside Ukrzaliznytsia or jointly with relevant ministries and universities—would function as the central platform for testing and scaling new digital solutions. Its core areas of focus would include smart ticketing systems, AI-driven predictive maintenance, automated scheduling tools, and enhanced cybersecurity measures, ensuring that innovation directly addresses operational needs.

2. Strengthening *public-private partnerships* represents the next essential component of this strategy. Collaboration with venture capital firms, technology accelerators, and international transport bodies such as Shift2Rail would make it possible to attract investment, exchange expertise, and accelerate adoption of new technologies. These partnerships could also support pilot projects on selected routes or regional hubs, enabling startups to validate their solutions in real operating conditions before scaling.

3. To further stimulate experimentation, Ukrzaliznytsia should introduce *regulatory sandboxes*—temporary, flexible regulatory frameworks that allow innovative transport technologies to be tested under controlled conditions. Such sandboxes would permit limited exceptions for experimental digital tools, provided that safety oversight mechanisms are in place. This approach would reduce regulatory barriers while still ensuring compliance with essential technical and safety standards.

4. *Close cooperation between universities and the railway sector* is another strategic direction. Ukrainian universities possess strong research potential and can contribute through joint R&D projects, hackathons, technology transfer initiatives, and incubator programs. Incentivizing intellectual property licensing from academic research would further encourage commercialization of university-generated innovations relevant to the railway industry.

5. *Open access to operational data* also plays a critical role in fostering an effective startup environment. By providing secure, anonymized datasets on train operations, infrastructure performance, and customer flows, Ukrzaliznytsia would enable startups to develop data-driven products, train AI models, and propose evidence-based improvements. Such transparency is a proven catalyst for innovation in the global transport

technology sector. However, expanding data access must be approached with caution: in a time of ongoing war, any digital openness increases the risk of cyberattacks from hostile actors. Therefore, strong cybersecurity protocols, encrypted data-sharing systems, and continuous monitoring are essential to ensure that innovation does not compromise national security or expose critical railway infrastructure to malicious interference.

Finally, the ecosystem must be reinforced by an incentivized procurement framework that prioritizes Ukrainian-developed IT solutions. Targeted startup grants, reduced taxation, preferential procurement policies, and innovation-friendly tender requirements would encourage domestic companies to pursue railway-focused innovations. This approach would not only reduce dependence on foreign technology but also strengthen the national digital economy.

Together, these six strategic elements form a coherent framework capable of transforming Ukrzaliznytsia into a catalyst for IT-driven innovation and supporting the emergence of a sustainable, competitive startup ecosystem within the Ukrainian railway sector.

Conclusions and prospects for further research. In this study, we examined foreign case studies of IT startups operating in the railway sector and identified practical ways in which Ukrzaliznytsia can apply their experience. The analysis demonstrated that innovations such as AI-based predictive maintenance, autonomous inspection systems, workflow optimization platforms, and modern communication technologies have already proven effective in Europe, Asia, and the Americas. These solutions can substantially improve operational efficiency, safety, and resilience of Ukraine's railway system, especially under wartime constraints.

We also outlined the key challenges that hinder startup development within Ukrzaliznytsia, including institutional resistance, regulatory rigidity, limited funding, and cybersecurity threats. Based on the SWOT analysis, we proposed a Strategic Framework consisting of six directions: establishing a

Railway Innovation Hub, strengthening public-private partnerships, introducing regulatory sandboxes, deepening university-industry cooperation, expanding secure access to operational data, and implementing an innovation-oriented procurement model. Together, these measures form a comprehensive approach to fostering an IT-driven startup ecosystem within the national railway sector.

Prospects for further research include developing a detailed roadmap for implementing this startup ecosystem, designing evaluation metrics for innovative pilot projects, and assessing the economic impact of integrating IT solutions into Ukrzaliznytsia's operations. Future studies should also explore cybersecurity models tailored to critical railway infrastructure and investigate long-term cooperation mechanisms with global transport innovation networks.

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