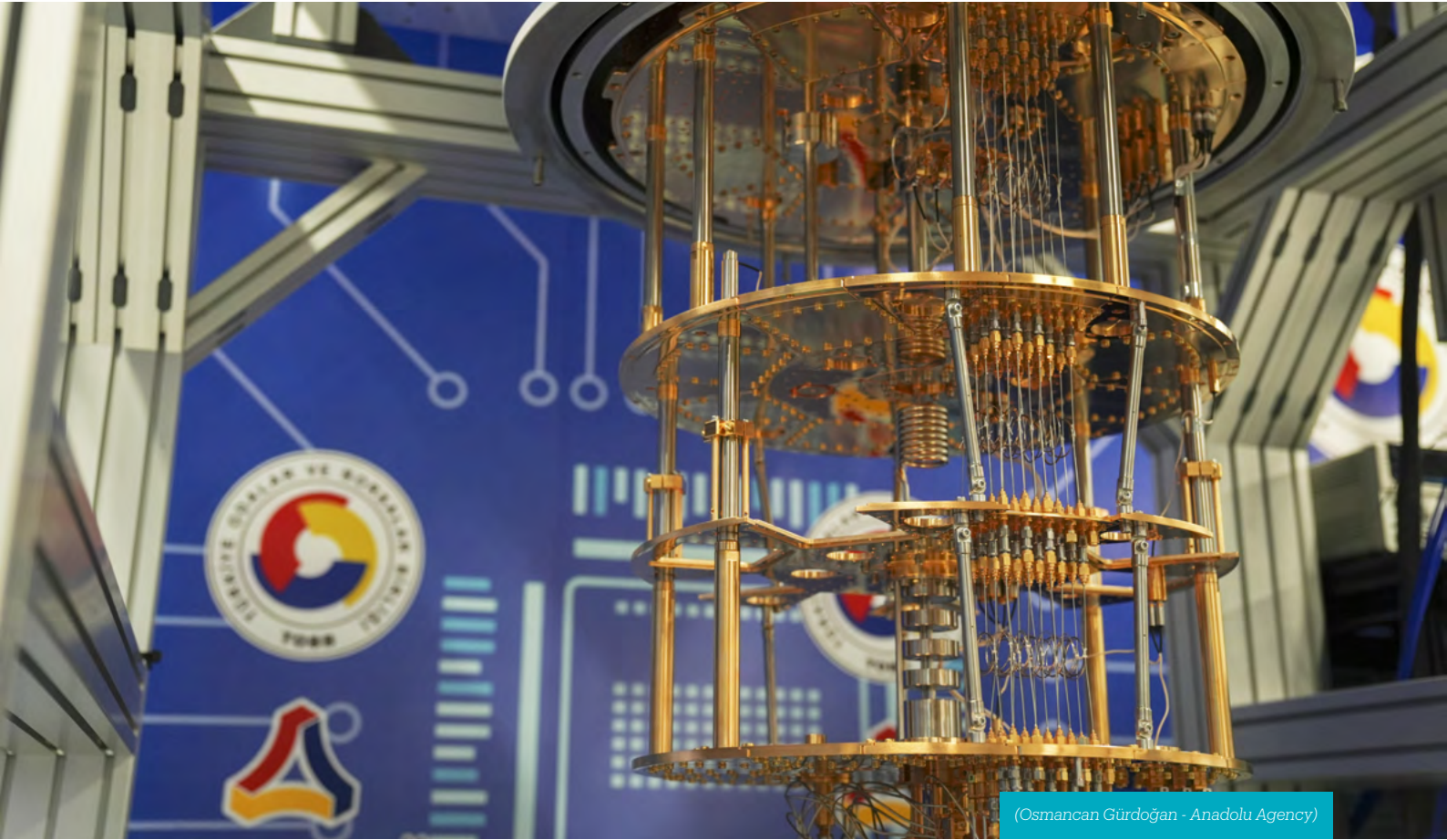


# Forging a Future-Forward Path: Türkiye's Embrace of Emerging Technologies

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**Türkiye is at the forefront of technological transformation, driven by rapid economic growth, a young tech-savvy population, and strategic initiatives like the National Technology Initiative (NTI). Emerging technologies like blockchain, quantum computing, virtual and augmented reality, space technology as well as digital twins are reshaping industries such as finance, healthcare, cultural tourism and urban planning. This policy outlook delves into how government policies, public-private partnerships, academic initiatives and local startups are driving these advancements. It underscores Türkiye's potential to transition from a consumer of global technologies to a major high-tech innovator shaping the next wave of digital transformation.**

## Emerging Technologies and Planning Ahead

Türkiye stands at the crossroads of technological development. In the past decade, rapid economic growth, a strategic geographic position, and a young and tech-savvy population have created fertile ground for the adoption and creation of state-of-the-art innovations. From blockchain financial tools and quantum computing labs to immersive cultural experiences, biotech breakthroughs, and digital twin simulations for smart cities, Türkiye is on track towards a more digital, connected, and future-focused society. This determination to move quickly in response to fast-approaching technological changes and advancements in emerging technologies has been encapsulated by the [National Technology Initiative](#) (Milli Teknoloji Hamlesi) or NTI.

The NTI is an all-inclusive framework for Türkiye's technological independence, innovation, and global competitiveness. It provides a strategic roadmap for the country to become a leader in high-tech industries by developing domestic capabilities and reducing reliance on foreign technologies. It aims to enhance the technological infrastructure of Türkiye and R&D and integrate advanced technologies in all sectors for a self-sufficient, knowledge-based economy. While the roots of Türkiye's technological transformation go further back, as noted in previous chapters highlighting earlier policies and reforms, it picked up steam in the last decade as part of a larger drive to better fit the country's development objectives to its centennial vision for 2023, its strategic goals by 2053 and beyond. The NTI involves strategic investment in critical areas of high technology, digital transformation, human capital development, infrastructure and innovation ecosystems. In terms of implementation, [Bilişim Vadisi](#) is deeply integrated with the NTI. Established in 2011 and operational since 2019, Bilişim Vadisi is Türkiye's largest technology development region located in the country's 'Mega Technology Corridor', providing infrastructure, entrepreneurship programs and funding to develop high-value technologies. With its focus on human capital development through educational and workforce development initiatives, Bilişim Vadisi aligns with the goals of the initiative and strengthens Türkiye's global competitiveness in advanced industries.

Along with analysing the impact of relevant government policy and programmatic efforts, this comprehensive investigation consolidates several emergent domains, each with a different potency in reshaping the industrial and daily dimensions of people's lives in Türkiye. Widespread adoption of blockchain platforms and crypto-assets evidences openness to financial innovation but, at the same time, signals a new age of secure and transparent value

chains. Similarly, the initial rapid strides in quantum computing, informed by academic excellence and international partnerships, illustrate how foundational science might seed applications that transform logistics, finance, and national security. In addition, immersive technologies can enrich cultural tourism, improve learning experiences, and increase the creative industries while at the same time showcasing the rich heritage and modern ingenuity of Türkiye to the world. In the medical field, new capabilities in biotech and personalised medicine create new solutions for historic health problems and may position Türkiye as a regional hub for pharmaceutical research and production. Against this backdrop, the nascent application of digital twins within urban planning, infrastructure management, and disaster preparedness underlines the national commitment toward more data-driven, resilient and citizen-centric policymaking.

This chapter, therefore, deals with the current landscape and potential for growth of each of these technologies in Türkiye, providing an overview of how the domestic context, public and private sector roles, regulatory frameworks, academic initiatives, and entrepreneurial ambitions underpin innovations on many fronts. This goes from government-driven incentive programs and public-private partnership initiatives to the creative force of startups and research organisations; each section illustrates various ways in which concepts are realised in reality. These developments point toward a future in which Türkiye positions itself not as a mere consumer of global technologies but as a serious contributor to the world's next wave of digital transformation.

## Blockchain Technology

Blockchain technology in Türkiye has seen a remarkable growth curve in recent years, driven by a [robust appetite](#) for digital assets and the country's commitment to innovation under the [National Technology Initiative](#) (NTI). As many as millions of Turkish users actively trade cryptocurrencies on platforms like BtcTurk and Paribu, reflecting widespread enthusiasm and advancing sophistication in digital finance. Beyond cryptocurrencies, blockchain applications are expanding into agriculture, where [traceability systems](#) help producers meet stringent international standards, and real estate, where [smart contracts](#) streamline transactions and enhance [transparency](#). The government has embraced blockchain through initiatives like the [digital land registry](#) pilot led by the Ministry of Environment, Urban Planning, and Climate Change, improving efficiency and security in public services.

Türkiye's approach to blockchain integrates traditional, digital, and regional markets simultaneously. While most jurisdictions are still debating central bank digital cur-

rencies, the Central Bank of the Republic of Türkiye has already tested the [Digital Lira](#), intending to make modern payments and financial inclusion more accessible. Regulatory bodies like the Banking Regulation and Supervision Agency have provided [sandbox environments](#) where innovative blockchain projects can develop relatively unhindered. The enthusiasm for increasing blockchain use cases, from consumer payments to land registries, shows the intent of the country to shape regulatory frameworks around real-world pilot implementations rather than wait for international consensus. This local-first, field-test-driven style contrasted with the more cautious or fragmented approaches of certain Western nations and allowed Türkiye to become a proving ground for early blockchain adoption in public services and finance.

Furthermore, the [financial sector](#) has also driven blockchain adoption significantly. Akbank collaborated with Ripple on blockchain-based money transfers, while Takasbank introduced a blockchain-based gold transfer system. Borsa Istanbul has created a secure platform based on blockchain for exchanging information in the financial field. It also received the interest of the logistics sector: TÜBİSAD cooperates with IBM in a blockchain supply chain. Blockchain solutions like Colendi and MenaPay present a local attempt: Colendi offers a decentralised credit-scoring platform that underbanked users can use to offer them microloans, while MenaPay is offering a Shari'a-compliant blockchain [payment gateway](#) and seeking to get on top of the financial needs in the Middle East and North Africa.

Blockchain research and education have advanced [significantly](#) under the NTI. Academic institutions such as BZLab, BAU BlockchainIST Center, and Istanbul University's Blockchain Innovation Center have become key players, integrating blockchain into curricula and fostering multidisciplinary research. Government-supported platforms like the Blockchain Türkiye Platform and the blockchain-based trade system implemented by the Ministry of Commerce underscore blockchain's growing role in public sector transformation. Türkiye has also demonstrated its research commitment with over 95 theses, 318 research articles, and active participation in events like TEKNOFEST, enhancing its reputation as a hub for blockchain innovation.

Türkiye's future in blockchain technology holds immense promise as the nation strengthens its position as a global export hub. Through the introduction of blockchain in textile and agricultural supply chains, Turkish companies not only promote transparency and trustworthiness but also attract international buyers committed to [responsible sourcing](#). Underserved communities now access safe, affordable financial systems through decentralised finance platforms designed to bypass all banking-related barriers. This makes Türkiye a strategically poised nexus at the crossroads between Europe, Asia, and the Middle

East, poised to be the hub for blockchain expertise and solutions. A regulatory framework that balances supportive oversight with a dynamic sandbox environment has created fertile ground for experimentation and innovation, attracting foreign investment and fostering rapid deployment of blockchain technologies. This comprehensive strategy sets Türkiye apart as a leader in blockchain adoption and innovation.

## Quantum Computing

Quantum computing in Türkiye, though still in its infancy, has gained considerable momentum through academic rigour, government initiatives, and nascent private-sector curiosity. Universities such as Bilkent and Koç lead this charge, where researchers delve into quantum algorithms, cryptography, and materials science to create a foundation on which larger-scale infrastructures can be built in the future. TÜBİTAK also plays an important role in supporting selected quantum-related projects by funding theoretical exploration and spurring practical applications that could eventually catalyse spin-offs and startups. This atmosphere of academic-industry collaboration opens ways to real-world quantum breakthroughs. The government's growing commitment is expressed through the National Technology Initiative. By November 2024, the country was set to [launch](#) its first quantum computer.

Instead of being confined to pockets of purely academic research or private-sector labs, synergy among universities, state agencies and domestic firms working together to develop quantum computing is encouraged. This inclusive strategy not only strengthens the knowledge ecosystem but also aligns well with the country's ambitions to become one of the 15 countries developing infrastructure for quantum computing: Türkiye plans to establish a [superconducting chip production](#) facility soon.

The government appears to understand the importance of the necessary human capital with scholarships and grants to transition from theoretical groundwork to commercialised solutions. Emphasis on partnerships, especially with European Union programs and most notably the Quantum Flagship, places Turkish researchers in contact with leading global experts and the latest research infrastructure, thus providing a way for Türkiye's quantum community to leap over some of the hurdles facing many emerging economies. Large-scale quantum computing installations are still on the horizon, but companies in all industries have already begun speculating how quantum technology can help hone their processes. ASELSAN, for example, is well-renowned in the fields of defence and aerospace, has been involved in numerous advanced R&D projects, and was [involved](#) in developing Türkiye's first quantum computer, as noted above. Similarly, TUSAŞ has shown interest in state-of-the-art [simulation techniques](#) that, in due course, can use quantum processors for better aerodynamics analysis.

The [notable quantum computing-related projects](#) in Türkiye before 2019 included academic and research institutions, as well as projects mainly in cryptography and sensing. BILGEM Quantum Cryptology Research Center was funded with 5.38 million TL (3.2 million USD at the time) by the State Planning Organization (DPT) for the development of quantum cryptography technologies, including quantum random number generators (QRNG). Applied Quantum Research Center of Izmir Institute of Technology, supported by the DPT with 4.46 million TL (2.67 million USD at the time), carried out foundational quantum research. Under QuantERA, the EU-funded quantum technology research network that the country joined in 2017, TÜBİTAK BILGEM contributed to the SQUARE Project on high-speed QRNGs on silicon chips, while Koç University completed the Quantum Cryptology Infrastructure Project in which 11 researchers worked on cryptographic systems. Furthermore, the National Metrology Institute (UME) participated in quantum sensing and metrology projects. In terms of strategic efforts, the goal of the Turkish government's strategic technology planning document '[Vision 2023](#)' was to develop basic quantum algorithms and systems of nanoscale quantum cryptology, while the Turkish Nanotechnology Strategy for the years 2017-2018 also mentioned quantum technologies, emphasising institutional efforts in this direction.

The model in Türkiye could be labelled cooperative development: robust state support with open international research networks. As Türkiye's quantum ecosystem evolves, the ongoing efforts in academia, government policy, and corporate interest all point toward a comprehensive strategy. Universities lay the foundational theories, the NTI channels resources toward practical outcomes and newly interested companies stand ready to translate these theoretical innovations into market-ready applications. Therefore, this interplay of research, policy, and enterprise shows that Türkiye means serious business as it seeks to chart its path by weaving local ambitions into global cooperation to make quantum computing vital to the nation's technological and economic progress.

## Virtual and Augmented Reality

Immersive technologies, especially Virtual Reality (VR) and Augmented Reality (AR), are changing how people enjoy themselves worldwide, and Türkiye is no exception. These technologies have revolutionised how people enjoy leisure, offering highly personalised, interactive and immersive environments. In Türkiye, where the tech industry is growing fast, the [integration of VR and AR](#) is increasingly visible in urban recreational spaces, entertainment venues, and educational institutions. These developments redefine not only leisure but also foster serious innovation in how people interact with both digital and physical worlds.

Government policies like the NTI and [2023 Industry and Technology Strategy](#) create an enabling environment for VR and AR growth through encouraging innovation, digital infrastructure, and supportive ecosystems for startups. The country's [Twelfth Development Plan](#) (2024-2028) has noted the importance of developing capacity for both AR and VR in multiple industries.

Several Turkish companies have taken front-line positions in developing VR and AR infrastructure, showcasing fast-developing immersive technology expertise. For example, artlabs.ai focuses on scalable 3D and AR production, bridging the integration between digital and physical commerce, leveraging AI to generate interoperable content for the metaverse, and positioning themselves as leaders within this emerging market. Another company, VR Sistem, provides VR and simulation technologies, offering tools for both entertainment and professional applications. These companies are driving Türkiye's progress in immersive technologies, aligning with global trends to innovate across industries.

COVID-19 fast-forwarded the pace of virtual recreation in Türkiye. Lockdowns and social distancing introduced people towards and drove interest in virtual events, online gatherings and digital gaming as alternatives to traditional leisure activities. This has [continued post-pandemic](#) globally, with the biggest growth in immersive technologies for tourism and education. For instance, the cultural richness of Türkiye makes it a perfect location for both VR-based virtual tours and AR-enhanced [heritage experiences](#), wherein users can virtually explore historical sites or interact with cultural narratives from their homes. With that said, there is also a growing demand for location-based entertainment. Müzeverse from VR Future shows how local startups use sophisticated tools to preserve and popularise cultural heritage and sell immersive content abroad. Such immersive storytelling also doubles as a form of cultural diplomacy, giving outsiders a chance to connect with Türkiye's heritage in ways previously unimaginable. The Turkish government, recognising the potential economic and cultural benefits, supports such endeavours through the Ministry of Culture and Tourism, offering financial aid to projects integrating VR and AR into heritage sites. The Digital Türkiye initiatives further strengthen this ecosystem by providing tax incentives and grants, encouraging entrepreneurs to push the limit of what's possible with immersive technology.

The future of immersive recreational technologies in Türkiye will be shaped by investment in infrastructure and international and local partnerships. Innovation hubs and content development will be critical in defining the nation's competitive edge, with a focus on Turkish culture. As immersive technologies continue to become more accessible and cost-effective, Türkiye is in a good position to act as a regional hub in digital recreation, merging rich cultural heritage with the latest technological advancements.

The commitment of the government to promote high-tech industries is also reflected in the Incentive Packages for High-Tech Production worth [30 billion USD](#), which indirectly supports the ecosystem for VR and AR by triggering innovation in hardware like chips and wearables. The combination of these policies and programs, alongside the endeavours of pioneering companies, provides a sound framework within which the immersive technology sector in Türkiye will continue to prosper, staying competitive and innovative at a global level.

## Space Technology

Türkiye has emerged as a significant player in the global space race, as it established the [Turkish Space Agency \(TUA\)](#) in 2018 and launched its ambitious [National Space Program](#) in 2021. The program represents a comprehensive approach to space development, combining technological advancement with [strategic national interests](#). Most recently, Türkiye achieved a major milestone by sending its first astronaut, Alper Gezeravcı, to the International Space Station in January 2024, joining an elite group of 22 nations with human spaceflight capability. The strategy includes participation in international space projects and establishing partnerships with other space agencies. The economic dimension of the space program is important: Türkiye aims to capture a share of the growing global space market while developing critical technologies that can contribute to other sectors. Besides technological development, the program emphasises commercial sustainability.

Türkiye's space program responds to the evolving [global landscape](#) where space activities are no longer dominated by traditional powers like the US and Russia; the field has expanded to include multiple nations and private entities. By January 2024, Türkiye had positioned itself strategically, operating 21 active satellites and ranking sixth in Europe and second in the Middle East for satellite operations. [Satellite development](#) forms a crucial component of Türkiye's space strategy. Starting from the first Turkish satellite launch, Türksat 1B, launched in 1994, many projects have since been under development to introduce domestic satellite production capabilities. While some satellites such as GÖKTÜRK-1 and various TÜRKSAT series were produced by international cooperation, Türkiye has increased its indigenous production capability, including the most recently launched [TÜRKSAT 6A](#). Similarly, the Regional Navigation and Timing System (BKZS) is another effort to gain independence in positioning and navigation. This system enables regional coverage using geostationary (GEO) and inclined geosynchronous orbit (IGSO) satellites. The applications are not restricted to navigation as they can be used in banking, transportation, agriculture, search and rescue, logistics, and military operations.

Another essential aspect of the program is enabling access to space. The country is developing its own indige-

nous launch vehicles. Many working groups are engaged in the [Access to Space and the Spaceport Feasibility Study](#), including mission payload, launch vehicle development, component technologies, and spaceport infrastructure. This aims to independently achieve space access by developing a commercially sustainable launch system.

Furthermore, the Space Weather Application Center (UHUM) has made [significant strides](#) in establishing its monitoring capabilities and forming connections with international space weather forecasting networks. This progress strengthens Türkiye's ability to predict and respond to space weather events that could affect national infrastructure and space assets. The [Moon Research Program](#) (AYAP) is one of the most ambitious projects. The program aims to develop indigenous spacecraft capabilities, including propulsion systems. While the AYAP-1 Moon Mission's original 2023 target for a hard landing was not achieved, development work continues on the spacecraft and propulsion systems, demonstrating Türkiye's commitment to achieving this milestone despite timeline adjustments.

Human resources development forms a critical component of the program. Türkiye realises that [training specialised personnel](#) for space applications is vital and has thus implemented programs to support education and internships in related fields. The strategy also involves raising public awareness about space activities and encouraging young people to pursue careers in the space sector. The [new agreements](#) signed by Türkiye with other space agencies and companies have broadened its framework of international cooperation. This will allow quicker technology transfer, sharing experience, and opening up opportunities for joint projects in space. All efforts continue to be coordinated under the TUA, which remains committed to implementing the National Space Program to position Türkiye as a major player in space technology development.

## Digital Twins and Türkiye's Smart Future

Infrastructure, manufacturing, and urban planning are some of the main areas that drive digital twin technologies in Türkiye beyond piloting into wider adoption. As virtual replicas of physical systems, [digital twins](#) allow engineers, planners, and operators to test scenarios and make data-driven decisions without risks and costs related to changes in actual environments. İstanbul Technical University (ITU) is undertaking an [innovative initiative](#) to create detailed digital twin models of the 81 provinces of Türkiye. This will be a significant change in urban planning and disaster preparedness methodology. The initiative's scope involves the systematic creation of digital twins across the whole administrative structure of Türkiye, including provinces and districts. These models will be important tools for comprehensive urban planning and

evidence-based decision-making on issues, including emergency response and infrastructure development in response to natural disasters. Linking these digital twins marks a significant advance in urban planning capability and disaster resilience for Türkiye. The broader vision is to proactively test solutions related to issues such as flooding, heat waves and surges in population before applying them in the real world.

The Istanbul Metropolitan Municipality (IMM) has a holistic urban transformation strategy for placing Istanbul as a sustainable metropolis by 2050, with equal opportunity in high-value urban services and infrastructure, via a project known as BIMİST. Among the keystones of this effort is that BIMİST was developed in cooperation with the IMM's Department of Housing and Urban Development and Autodesk BIM applications to digitalise the building permit and approval process. The municipality's strategic goal is to create a [detailed digital twin](#) of the city, including comprehensive infrastructure and superstructure layers. Such a digital transformation initiative represents significant advances in construction management and urban planning methodologies. The BIMİST project constitutes the basic ingredient for citywide digitalisation, a step that has been making urban development challenges more efficient and organised. A similar approach is taking shape in Izmir, where local authorities consider how the digital twinning of neighbourhoods might enable better tasks like managing the dispatch of emergency services more precisely. The Izmir Metropolitan Municipality's integration into the Open and Agile Smart Cities (OASC) Network marked a [significant advancement](#) in Türkiye's smart city development. Partnering with Istanbul to establish OASC Türkiye, Izmir gains access to a global network of 152 smart cities, positioning itself to benefit from international best practices and innovations in urban development.

Among the manufacturing industry initiatives launched by [TUBITAK](#), the digital twin technology takes centre stage and creates a production environment virtually in real-time. Digital twins integrate data from production systems, energy monitoring and IoT Sensors at both machine and production Line levels. This allows for predictive maintenance, flexible production management and automated breakdown detection. The technology builds virtual representations that could be used for real-time monitoring and feedback, enabling unmanned operations and efficient stock management. TUBITAK prioritises developing digital twins with complementary technologies such as industrial cloud services, virtual data spaces, and edge computing solutions. This integrated approach positions the digital twin within a larger ecosystem of knowledge-based production solutions supported by large-scale testing and experimentation centres. To highlight the [impact](#) digital twin technology is making in Turkish manufacturing, Turkish consumer giant Arçelik partnered with an Istanbul-based startup called Simularge to develop a digital twin solution

that was able to integrate real-time sensor data to achieve operational improvements that saved more than 2 million USD annually. The success has catalysed broader digitalisation initiatives across the organisation and beyond. These innovative partnerships promise substantial long-term cost savings and enhance the global competitiveness of Türkiye, especially since the country seeks to be a key manufacturing hub between Europe and Asia. The government has an important role in scaling these innovations nationally through the Ministry of Environment, Urban Planning, and Climate Change.

The application of digital twins can help refine traffic flow, optimise resource allocation, and guide future construction in cities across the country, saving public funds that might otherwise be spent on trial-and-error solutions. As Türkiye refines its expertise in simulating complex systems, it also gains a competitive edge in the burgeoning global market for smart city technologies. The neighbouring countries in the Middle East, North Africa, and Eastern Europe can learn from the pilot programs of Türkiye and possibly adopt similar strategies for digital twins to tackle water shortages or outdated transport networks. That would place Türkiye, a country willing to experiment with digital twins in field projects and share gained knowledge with regional counterparts, into a position where it would become a beacon of modern urban governance, also catalysing the adoption of intelligent solutions across different verticals.

## Making Innovation Sustainable

As Türkiye advances on its trajectory of technological innovation, it needs to be guided by the tripod of sustainability, resilience, and long-term impact for the next wave of progress. Tapping into emerging technologies like blockchain, quantum computing, virtual and augmented reality, space technology, and digital twins requires bold vision and strategic alignment in regulations, infrastructure, human capital, and cultural insight. These regulatory frameworks should be clear and allow room for creativity, especially through sandbox environments that would really provide a space to experiment while protecting consumers and investors alike. Public-private partnerships underpinned by properly structured funding mechanisms further this collaboration between government agencies, universities, established companies, and agile startups, assuring that innovation is part of the general social and economic context. Human capital development must be highly purposive, with specialised training, scholarships, and interdisciplinary initiatives that will adequately prepare future professionals for challenges at the scientific frontier.

Investments in infrastructure, be it secure high-performance computing resources, quantum labs, biotech test-

ing facilities, or robust telecommunications networks, can then amplify the creative capacities of an increasingly skilled workforce. Extending these national efforts into global research consortia and multinational partnerships will accelerate technology adoption, including introducing global best practices, to ensure that Türkiye remains competitive in responding to local needs. Clearly, one of the most direct ways to sustain momentum around innovation is to connect emergent technologies with national priorities and cultural values. By integrating blockchain into the agricultural supply chain, immersive media into tourism, quantum computing into export logistics and digital twins into urban and disaster-management planning, Türkiye can ensure that technological breakthroughs permeate everyday life and are not confined to the ivory towers of niche research laboratories.

Equally important will be the maintenance of feedback loops and performance indicators that enable policymakers and industry stakeholders to assess progress, diagnose challenges, and adjust strategies in a transparent and flexible manner. This responsive governance would help Türkiye avoid mistakes, reduce risks and build solid trust in its citizens, investors, and collaborators. Each in its own right, the approaches undergird the notion of sustainability to expand beyond environmental impact to realms of social equity, economic competitiveness, and cultural stewardship. Instead of adopting only international innovations, it is ambitiously required that Türkiye create and export transformative solutions that, along with being cutting-edge, would be ethically sound and have strong reflections of the heritage and strategic positioning of the country. With policy support, infrastructure investments, educational reforms, and international engagement in harmony, Türkiye can move confidently toward a future in which emerging technologies underpin a lasting culture of innovation and inclusivity, making sure that breakthroughs serve the collective good and fortify the nation's role as a leader in the interconnected, digitally driven new world.