NATIONAL TECHNOLOGY INITIATIVE AND AI INTEGRATION

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Abstract

The National Technology Initiative aims to increase local production capacity and ensure technological independence for Türkiye. The role of artificial intelligence is strongly emphasized among high technology areas, recognising the power of digital transformation technologies. This chapter overviews the vision of producing high value-added solutions based on advanced technology and their strategic directions, including the 2030 Industry and Technology Strategy. The Turkish Large Language Base Model and the new AI cluster of the Turkish National Science e-Infrastructure ARF ACC are provided as key national projects. The TÜBİTAK Artificial Intelligence Institute that is established based on the National Artificial Intelligence Strategy and acts as a bridge between academia and industry is overviewed with its thematic areas of smart manufacturing systems, climate change and sustainability, smart agriculture, food, and livestock, smart education technologies, and financial and e-commerce technologies. The Artificial Intelligence Ecosystem Calls and advances in artificial intelligence within the scope of TÜBİTAK High Technology Platforms are represented with illustrative examples. In a future outlook, the Artificial Intelligence Roadmap with layers based on technological goals, critical products and technologies, and critical sectoral needs is shared along with the framework of prioritised R&D and innovation topics. These developments and others are placed in the context of becoming an attraction centre for top scientists in the region and around the world and a production hub for advanced technologies, including scientific and technological breakthroughs in artificial intelligence. Pioneering advances from international fellows and institutional leadership at the global scale are underlined. Advances in artificial intelligence technologies and solutions are being enriched with aligned strategic directions at the national level and the dedication of researchers, young human resources, and institutions within the research, development, and innovation ecosystem. Together, the research, development, and innovation ecosystem is working in collaboration to make the guiding vision for the Century of Türkiye a reality.

Keywords

Artificial Intelligence, Digitalization, Research, Development, Innovation, National Strategies

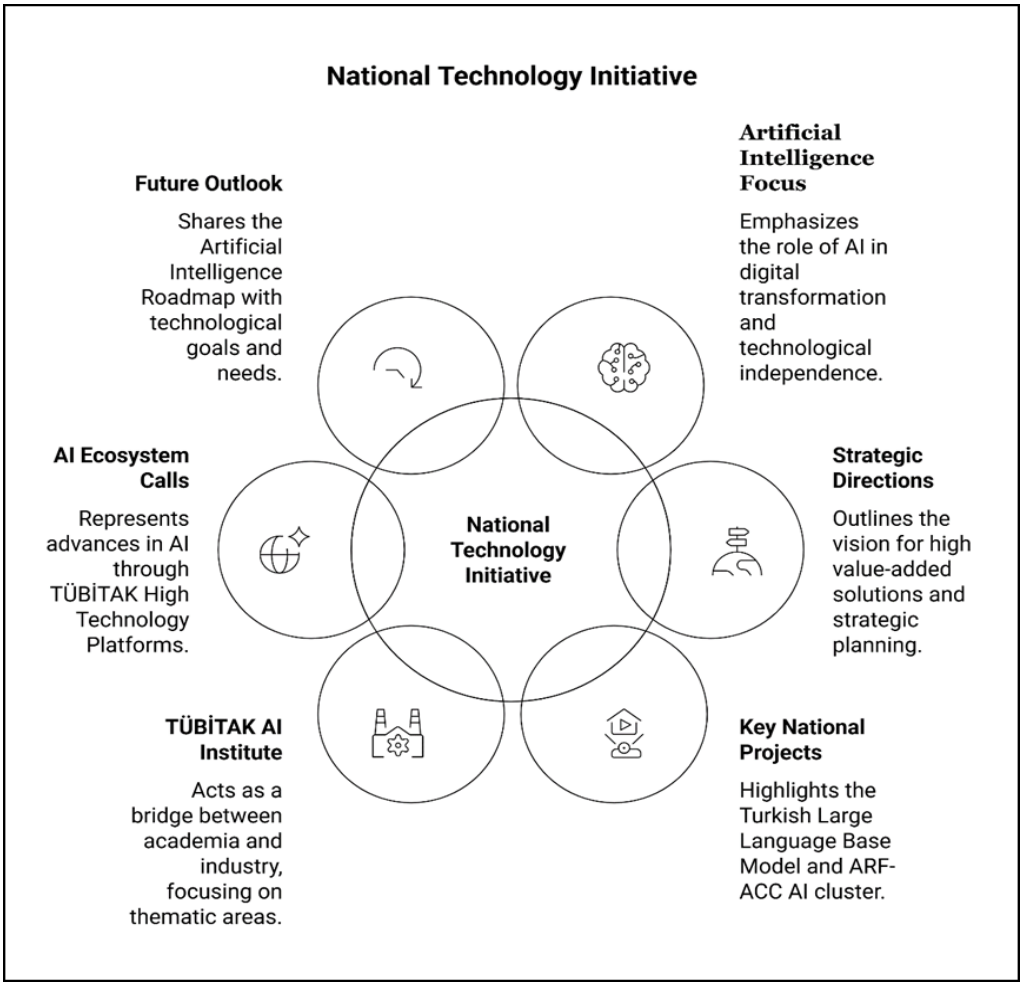
Introduction: Transformative Role of Artificial Intelligence and Türkiye

Artificial intelligence stands at the core of Türkiye's transformation agenda, not only as a driver of productivity and innovation, but also as a foundation for national resilience. The National Technology Initiative offers a broader framework that links technological independence with progress driven by AI. It sets out Türkiye's long-term goals for technological sovereignty, aiming to secure independence in critical technologies, strengthen supply chains, and build strong national capabilities in areas such as AI, cybersecurity, data governance, and high-performance computing. Within this vision, AI is seen not merely as a technology, but as a strategic force that supports national priorities, from defence autonomy and industrial competitiveness to scientific excellence. The Initiative also calls for reducing dependence on imported technologies, nurturing local innovation ecosystems, and promoting a secure and ethical digital transformation. As outlined in the National Technology Initiative defined by the Turkish Academy of Sciences (Kacır etal., 2022), Türkiye aims to turn its scientific and technological strengths into a globally competitive and self-reliant innovation system.

Building on this strategic foundation, it becomes clear why AI occupies a central place within the National Technology Initiative. Beyond its global influence, artificial intelligence represents a transformative capability that enables Türkiye to strengthen its innovation ecosystem, reduce technological dependency, and enhance national competitiveness in the new digital era.

Figure 1

TÜBİTAK's Main Roles in Turkish AI Ecosystem



As shown in Figure 1, with a focus on the National Technology Initiative and AI integration, this chapter first overviews the Twelfth Development Plan, the 2030 Industry and Technology Strategy, and the National Artificial Intelligence Strategy of the Republic of Türkiye, important national projects, and competitions for young human resources. These strategic frameworks are then placed in the context of the establishment of the TÜBİTAK Artificial Intelligence Institute, along with its calls for the research, development (R&D), and innovation ecosystem. The thematic areas of collaboration are provided and supported by reviews from the scientific literature, with a focus on around 40 systematic reviews that are selected based on their relevance and published between 2024 and 2026. The chapter then proceeds to AI-oriented solutions within High Technology Platforms and concludes with an outlook towards targeted progress in AI based on technology roadmaps as well as contributions at the global scale.

1. National Technology Initiative and Strategies for Artificial Intelligence

Within the implementation of this Initiative, the Ministry of Industry and Technology plays a central role through flagship programs such as the Technology-Oriented Industry Initiative (HAMLE) and the High Technology Investment Program (HIT-30). These programs directly stimulate AI-driven transformation in manufacturing, mobility, and energy systems, enabling end-to-end technological development from R&D to market adoption. Moreover, the Türkiye Technology Team Foundation (T3 Foundation) contributes actively by fostering entrepreneurship, talent development, and applied AI training programs. Its AI-focused initiatives, including the T3 AI Lab, national hackathons, and mentorship for young innovators, complement TÜBİTAK's ecosystem-building efforts by mobilising a new generation of AI practitioners.

Together, these efforts demonstrate how the National Technology Initiative operates in practice; connecting national ambition with concrete actions that strengthen Türkiye's innovation capacity. Building on these implementation mechanisms, Türkiye's strategic policy documents provide the overarching direction and long-term vision for AI development, ensuring that institutional initiatives and national strategies move in harmony.

The Twelfth Development Plan of the Republic of Türkiye provides strategic direction for supporting the rise of AI technologies across sectors (Presidency of the Republic of Türkiye / Presidency of Strategy and Budget, 2023). The plan strongly recognises the acceleration in the development of AI and its influence on competitiveness while being conscious of the need to direct advances towards societal benefits. One of the key policies and measures of the plan is to support the development of key technologies in the field of AI and expand their use to address a multitude of needs by strengthening the R&D and innovation ecosystem. Collaboration among the public sector, universities, and the private sector is particularly emphasized alongside international cooperation. Another guiding objective is to become an attraction centre for top scientists in the region and around the world in critical fields, including AI, and to become a production hub for advanced technologies. Such strategic directions underpin the guiding vision of the plan as "a stable, strong and prosperous Türkiye, that is environmentally friendly, resilient to disasters, produces high added-value based on advanced technology, and shares income fairly in the Century of Türkiye (Presidency of the Republic of Türkiye / Presidency of Strategy and Budget, 2023)." The 2030 Industry and Technology Strategy and the National Artificial Intelligence Strategy of Türkiye take these national strategic directions forward.

As a centre point for national technology strategies, the National Technology Initiative aims to increase local production capacity and ensure technological independence for Türkiye. Based on this Initiative, the 2030 Industry and Technology Strategy of the

Ministry of Industry and Technology underlines the role of AI among high technology areas and emphasizes the power of digital transformation technologies (Ministry of Industry and Technology of the Republic of Türkiye, 2025a). Within this key national initiative, the Technology Oriented Industry Initiative Program (HAMLE) has supported more than 100 projects for digital transformation and emerging innovative technologies (Ministry of Industry and Technology of the Republic of Türkiye, 2025c). These projects are to contribute to the expectation of obtaining an estimated 5% increase in gross domestic product through the economic contribution of AI technologies in Türkiye. The High Technology Investment Program (HIT-30) is another opportunity in the national ecosystem to stimulate these benefits through an integrated, end-to-end approach for technological investments (Ministry of Industry and Technology of the Republic of Türkiye, 2025b). Digital technologies, particularly AI, quantum technologies, data centres, and Large Language Models are among the prioritised areas of this program, where the R&D and innovation ecosystem is already making important advances. The Scientific and Technological Research Council of Türkiye (TÜBİTAK) actively works to support the R&D and innovation ecosystem in these areas and to become one of the leading countries of the technology era by transitioning to the digital economy and fostering high-technology advances (Aydın, 2025).

1.1. National Advances in Large Language Models and Supercomputers

In the scope of Large Language Models, a key project is the Turkish Large Language Base Model of the TÜBİTAK Artificial Intelligence Institute, established under the TÜBİTAK Informatics and Information Security Research Center (BİLGEM) and operates in close collaboration with the BİLGEM Information Technologies Institute (BTE) to serve as a bridge between academia and industry. The project is developing generative AI solutions that are specific to the Turkish language with a dataset of 1 trillion tokens (Ministry of Industry and Technology of the Republic of Türkiye, 2025a). Beyond text processing, multimodal AI systems that are capable of processing multiple data types, such as images and audio, are being developed. These advances are recently supported with a new call to support industry-specific adaptation of AI transformation processes, smart solutions, and the performance of multimodal tasks based on the Turkish Large Language Base Model (Anadolu Agency, 2025a). The TÜBİTAK Artificial Intelligence Institute is the first institute structured with a perspective of bringing the entire ecosystem of the sector together in a critical technology area, and serves as a model for other emerging technology areas. Key competencies of the national ecosystem, including novel reinforcement learning approaches that outperform baseline algorithms (Haklıdır & Temeltaş, 2021), continue to be brought together in related initiatives. With the achievement of the Turkish Large Language Base Model as a top priority, TÜBİTAK is working to increase interactions across the R&D and innovation ecosystem, including its sectoral adaptations.

High performance computing is another area where important strides are being made, particularly through the new supercomputer of the Turkish National Science e-Infrastructure (TRUBA). This infrastructure of the TÜBİTAK National Academic Network and Information Center (ULAKBİM) now contains the country's highest capacity supercomputer, namely ARF, and the new AI cluster, the ARF ACC system, providing computational resources for researchers working with AI technologies. In the latest GREEN500 list, ARF ACC ranked 45th globally based on energy efficiency metrics, with an efficiency of 52.55 GFlops/W (TOP500, 2025). Moreover, TÜBİTAK is a partner of MareNostrum5 consortium at the Barcelona Supercomputing Center and its related activities, as well as the new Artificial Intelligence Factory consortium (MareNostrum 5+) as one of the first seven AI Factories to be supported by the European High Performance Computing Joint Undertaking to accelerate the industrial and public AI ecosystem (Barcelona Supercomputing Center, 2025). Similarly, AI is elevated to take centre stage in all support programs and scholarships to ensure prioritisation of this technology area with utmost coherence (Anadolu Agency, 2025b).

1.2. Human Resources, Entrepreneurship, and Widespread Mobilisation

Key developments have a basis in the country's first national strategy document in the field of AI, namely the National Artificial Intelligence Strategy of Türkiye, which provided a framework with 24 objectives and 119 measures, including the establishment of the TÜBİTAK Artificial Intelligence Institute (Ministry of Industry and Technology / Presidency of the Republic of Türkiye Digital Transformation Office, 2021). The vision of this national strategy is "creating value on a global scale with an agile and sustainable AI ecosystem for a prosperous Türkiye." The strategies cover human resources with a focus on training AI experts and increasing employment in the domain, and extend to supporting research, entrepreneurship, and innovation. The strategies also cover broader perspectives, such as facilitating access to quality data and technical infrastructure, regulating to accelerate socio-economic adaptation, strengthening international cooperation, and accelerating structural and labour transformation. In aspects of entrepreneurial opportunities, it is also important to note that the TÜBİTAK BiGG program has led Türkiye to become one of Europe's leading centres for technology-based entrepreneurship, including entrepreneurs in AI related solutions.

Moreover, competitions of the TEKNOFEST Aerospace and Technology Festival have mobilised the development of essential skills in AI in young human resources, including through the numerous competitions organised by TÜBİTAK and other partners that range from space to biotechnology and integrated circuit design to AI technologies (TÜBİTAK, 2025f). Overall, the TEKNOFEST Aerospace and Technology Festival attracted more than 1.2 million competitors in 2025 as the widest participation and richest content to date. Just two examples of the technology

competitions are the Artificial Intelligence in Aviation and Artificial Intelligence in Health, where young human resources developed innovative solutions in these fields (TEKNOFEST, 2025). The Blockchain Competition and Chip Design Competition are other examples where young technology enthusiasts are encouraged to explore and develop technological solutions or tackle real-world problems. In the Quantum Technologies Hackathon, young human resources engaged with quantum neural networks and quantum metrology applications. Even at earlier ages, young human resources have the opportunity to participate in Deneyap Technology Ateliers as well as other science and society activities.

2. TÜBİTAK Artificial Intelligence Ecosystem Calls and Interactions

The Artificial Intelligence Ecosystem Call of TÜBİTAK contributes to transforming AI technologies into products or solutions in line with the needs of partner and customer institutions while stimulating the R&D and innovation ecosystem. The call encourages customer institutions that require AI solutions to develop solutions by forming consortia with at least one customer company as a large firm or small and medium-sized enterprise (SME), a technology provider SME, an experienced university, a research laboratory, or public research centre, and the TÜBİTAK Artificial Intelligence Institute. The priority areas of the call are aligned with thematic areas for establishing the critical mass of ecosystem actors who are actively engaged with the Institute. Since 2022, the first three annual calls supported 41 projects, which involve multiple stakeholder consortia in collaboration with the TÜBİTAK Artificial Intelligence Institute, with over Ł215 million (TÜBİTAK, 2025e).

More specifically, the call aims to transfer embedded know-how to companies, support SMEs and entrepreneurial institutions within the AI ecosystem, guide actors of the R&D and innovation ecosystem towards an active collaboration model through the TÜBİTAK Artificial Intelligence Institute, and develop human resources to conduct research in the field of AI. Acting as a catalyst, the responsibilities of the Institute span across the fundamental integration of the developed solutions and the transfer of the accumulated knowledge to the R&D and innovation ecosystem. The Business Analysis Units support this process by disseminating lessons learned across other projects. Moreover, transfer laboratories establish an anonymized use case database, reusable software libraries, and a solutions catalogue that can be used to mobilise additional AI actors in the R&D and innovation ecosystem.

Complementing this ecosystem-oriented approach, the 1007 Public R&D Programme has introduced Public AI Ecosystem Calls, enabling ministries and public agencies to articulate mission-oriented AI needs and coordinate large-scale innovation efforts. These calls mobilise interdisciplinary teams from universities, research centres,

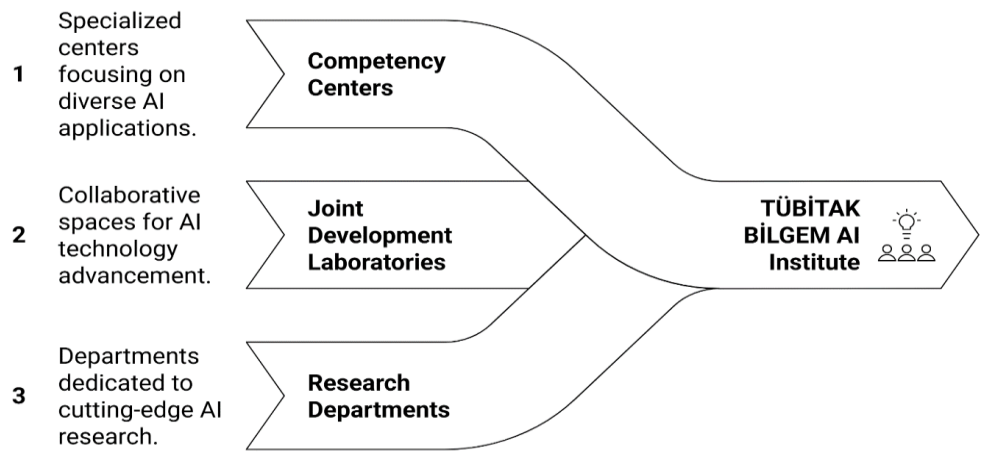
TÜBİTAK institutes and industry, and have already led to the development of AI-driven solutions in areas such as insurance regulation, social security analytics and wider public-sector digital transformation.

3. TÜBİTAK Artificial Intelligence Institute and Advances in Thematic Areas

The TÜBİTAK Artificial Intelligence Institute has been established based on a collaborative model with the R&D and innovation ecosystem to uphold principles of co-creation and the development of solutions together with a multitude of stakeholders to ensure impact, as shown in Figure 2. The Institute focuses on the transformative potential of AI and realises pioneering efforts to create and sustain innovation, economic growth, and productivity in Türkiye through advances in the field of AI. The Institute acts as a bridge between academic research and industrial needs for the discovery of pioneering, inclusive, and sustainable solutions, technologies, and products, as emphasized in national strategies. The Institute continues to work as a catalyst within the ecosystem and for establishing the next-generation workforce that is capable of responding to national priorities and global trends (TÜBİTAK YZE, 2025k).

Figure 2

The Layered Structured of TÜBİTAK BİLGEM AI Institute



A particular emphasis is placed on interactions with competent researchers, private sector firms and entrepreneurs, public institutions, and young researchers to stimulate multi-disciplinary problem-solving opportunities (TÜBİTAK YZE, 2025e). The Institute has a multi-layered structure based on competence centres, research departments, and co-development laboratories, all with interactions and connections to the R&D and innovation ecosystem. The competence centres are structures where

different research departments or units gather around thematic areas and coordinate their work towards creating impact (TÜBİTAK YZE, 2025c). Researchers are brought together to form research teams in these thematic areas from different research departments across the country. Moreover, these centres are intended to be used to collaborate with stakeholders to identify researcher-focused topics and facilitate pre-competitive collaboration. Throughout the process, stakeholders are encouraged to interact with competence centres according to the thematic areas and create advantages for future collaborations, especially through the relevant calls of TÜBİTAK. The collaborations involve the stages of blueprint, test, proof of concept, prototype, demonstration, and transfer laboratory. Six competence centres are established, namely those on smart manufacturing systems, climate change and sustainability, smart agriculture, food, and livestock, smart education technologies, and financial and e-commerce technologies.

The research departments are units that are focused on the sub-technologies of AI and develop core technologies in their specialized fields to provide solutions to relevant, real-world problems (TÜBİTAK YZE, 2025g). The research departments extend across university research centres and laboratories, public research centres and institutes, technology-based startups, and SMEs that partner with the Institute through projects and platforms. Here, the sub-technologies include computer vision, augmented reality, augmented vision, speech recognition and natural language processing, smart assistants, expert systems, remote sensing, big data analytics, smart communication, and embedded intelligence. These also extend to Internet of Things, robotics, smart automation, smart human-machine interfaces, digital twins, robotic process automation, emotion and mood analysis, and medical imaging. Lastly, the co-development laboratories aim to establish active and long-lasting platforms for solving problems jointly with public institutions and private sector industry partners (TÜBİTAK YZE, 2025b). Collaborations within co-development laboratories can involve working groups that are supported by the Business Analysis Units and transfer laboratories, and can involve pilot production, process development, and pre-competitive collaboration environments.

3.1. Relevant Trends and Advances for Smart Manufacturing Systems

Manufacturing systems that are smart, digital, flexible, and sustainable have multiple enabling technologies and applications, including digital twins to simulate and optimise operations and robotic systems. AI continues to be used to optimise robotic paths, schedules, material handling, human-robot interactions, and even robot digital twins (Qin et al., 2026). In addition, additive manufacturing has advanced from a prototyping tool into a technology for standard manufacturing processes through progress in AI, such as optimising process parameters, processing of materials, and quality control (Pancholi et al., 2025). Within the scope of smart manufacturing

systems, AI-based predictive maintenance is another area that requires cutting-edge analytics and sensor data to forecast reliability before faults take place in machines and equipment, including manufacturing processes for the aerospace, automotive, and transportation industries (Uçar et al., 2024). Recent advances and future trends in this area include advanced algorithms, edge and cloud computing for real-time analysis, and zero-touch maintenance operations.

Within these advances, the focus of the TÜBİTAK Artificial Intelligence Institute on smart manufacturing systems works to increase human-machine interaction in industries, increase production efficiency, provide process-effective solutions, and establish joint development sites for model factories (TÜBİTAK YZE, 2025j). The main stakeholders include those in automotive, machinery, and engine production sectors, defence, chemistry, pharmaceuticals, medical devices, and others. Some of the application areas include real-time situation analysis of production with AI sensors, demand estimation by modelling customer purchasing behaviour, robot automation, digital twins of production sites, reinforcement learning techniques for autonomous robots, and value addition in processes. Projects together with the Turkish AI ecosystem include those on image processing and analysis in automotive factories, increasing the production efficiency of nano coatings, predictive maintenance activities in wind turbines, forecasting technologies for new chemical formulas with optimised performance, and warehouse management. Some other example projects with the Turkish AI ecosystem also include digital twins for moulding processes, predictive smart manufacturing system for welding processes, quality control systems, object detection models, next-generation metal cutting machines, cost estimation software, and optimisation for the glass industry.

3.2. Relevant Trends and Advances for Climate Change and Sustainability

In the era of climate change, extreme hydrometeorological events are intensifying in frequency and severity, and their impacts are escalating. Flood and drought risk management and information systems that can utilise cutting-edge technologies for top analytical capabilities have emerged, although more collaboration between professionals is critical to improve their functionalities (Yeşilköy et al., 2024). In addition, marine heatwaves, which have socio-economic and environmental impacts on coastal economies and marine ecosystems, can be detected and forecasted using machine learning techniques (Welandawe et al., 2025). Beyond such applications and early warning systems, AI has a critical role to play from the perspective of supporting society to mitigate greenhouse gas emissions that are causing climate change and its widespread impacts. Some other example approaches that are based on AI can be used to support decisions that are related to industrial supply chains to reduce carbon dioxide emissions, including through optimised logistics and green supply chain management (Vishwakarma et al., 2025).

In the scope of energy, optimisation techniques based on AI are essential for the energy transition, including in the design and operation of power systems that are adaptive, resilient, and sustainable (Krishnamurthy et al., 2026). Large Language Models are also proving capable of improving data fusion to support AI applications in the energy sector, such as for managing and predicting renewable energy generation in smart grids, as well as their digital twins (Antonesi et al., 2025). Moreover, load management, energy performance, flexibility, voltage stability, and resilience are being improved through AI-based solutions in energy system infrastructure and microgrids with high penetration of variable renewable energy sources (Khosravi et al., 2025). In the wind energy sector, techniques based on AI have the potential to optimise, forecast, and control the performance of wind turbines and increase the efficiency of onshore and offshore wind farms, including through methods based on artificial neural networks (Dörterler et al., 2024). For green hydrogen production systems, AI is being used for cost analysis, the optimisation of electrolyser operations, and integration with variable renewable energy sources as a key power-to-X option, as well as process control (Askr et al., 2025). Another area where optimisation strategies based on AI are opening new possibilities is marine renewable energy, including site selection, cost reduction, and efficient generation (Tang et al., 2025).

Aspects of sustainability extend to sustainable supply chains and pollution monitoring. For example, AI is providing new options in environmental toxicology and the monitoring of environmental pollution more effectively to avoid public health issues from air, water, and land pollution to support environmental sustainability (Ajakwe et al., 2025). In addition, solutions for the circular economy and ecological decision support systems are being enabled through AI-based techniques within environmental research and technologies (Okafor et al., 2025). For sustainable buildings and communities, new trends that are related to generative AI are leading to new technological innovations for automating workflows across the stages of design, planning, and construction, including parametric design and evaluation (Alwashah et al., 2025). At the urban scale, efficient urban planning that is able to manage increases in urban population, accessibility, and transport demands is being supported by spatial analyses and simulations that are driven by AI-based approaches (Liao et al., 2025).

The thematic focus of the TÜBİTAK Artificial Intelligence Institute on climate change and sustainability emphasizes reducing greenhouse gas emissions in various sectors, particularly through increasing renewable energy utilisation, protecting carbon sinks and forest areas with remote sensing methods, and certain aspects of regional climate modelling and impacts (TÜBİTAK YZE, 2025a). The application areas include the consideration of weather conditions in forecasting renewable energy production, energy generation optimisation, intelligent traffic management, and monitoring of

greenhouse gas emissions. Projects in this thematic area together with the Turkish AI ecosystem include those on carbon footprint source tracking, capacity optimization in electrical distribution networks, monitoring the effects of climate change, sustainable transportation for tourism, an AI-based control algorithm for the recovery of wastewater from the textile industry, automation-supported textile dyeing and etc. There are a multitude of other opportunities in this thematic area, including additional involvement with technology-based start-ups. Specifically, new entrepreneurial opportunities are arising rapidly based on AI applications within the sustainability domain, including those that can be termed as sustainable entrepreneurs (Abbas & Bulut, 2024).

3.3. Relevant Trends and Advances for Smart Agriculture and Food Supply

In the agricultural sector, computer vision, deep learning, robotics, drones, and Internet of Things are contributing to smart agricultural systems with earlier and more robust detection and management of plant diseases (Yılmaz et al., 2025). Precision agriculture, predictive modelling of crop yields, and remote monitoring are related areas where AI is supporting agricultural systems and their supply chains for food security (Rejeb et al., 2025). Multimodal Large Language Models also have potential to optimise agriculture processes, reduce costs, increase crop yields, control crop management, and diagnose plant diseases, including through advanced image recognition (Sapkota et al., 2025). Automation in vertical farming systems and smart greenhouses is another area where AI is being used to develop proactive strategies for plant growth, nutrient solutions, and crop responses to lighting, humidity, and hydroponic conditions (Kaya, 2025). In addition, data-driven systems for aquaculture are supported by AI, including those for early disease detection and pollution risk analysis, and such systems are projected to rise in the next years (Çakır et al., 2026).

Similarly, recent trends are emerging in the agriculture and food system, including solutions in the food industry based on AI that are enabled by machine learning algorithms. Such trends have focused on sustainability, the prediction of food demand, the prediction of the shelf life of packaged foods, nutritional analyses, and means of reducing food waste (Yang, Jiao, et al., 2025). For food safety, AI is being used to provide early warnings of outbreaks, predict risks, and both detect and identify food-associated pathogens before they may affect public health (Rugji et al., 2025). Overall, data analytics, machine learning, and robotics are transforming sustainable farming practices and agribusinesses, while ethical challenges remain for ensuring technological and digital equity among farmers (Bhat et al., 2025). Solutions in this thematic area require multi-disciplinary collaborations more than ever.

To address these opportunities and provide new solutions, the focus of the TÜBİTAK Artificial Intelligence Institute on smart agriculture, food, and livestock relates to AI-based solutions for food companies, quality compliance of food products, the

estimation of crop yields from satellite images and soil analysis, and livestock scenarios (TÜBİTAK YZE, 2025h). The main stakeholders are companies in the sector and public institutions, especially the Ministry of Agriculture and Forestry, the General Directorate of Food and Control, and the General Directorate of Livestock. Some of the application areas include drones, robots and sensors, remote sensing and computer vision for pest reduction, prediction of weather conditions and precipitation, optimisation of process parameters, and autonomous systems in food production. Projects developed together with the Turkish AI ecosystem focus on precision agriculture, autonomous plant-health detection using unmanned aerial vehicles, functional food design, pollen classification, herd management, etc.

3.4. Relevant Trends and Advances for Financial Technologies and E-Commerce

The relevance of big data analytics and AI for the finance industry is apparent based on the need for improving the convenience, affordability, and efficiency of financial services, the performance of financial institutions, including financial stability, and ensuring efficient financial transactions (Najem et al., 2025). Financial forecasting, financial fraud detection, risk management, and digital insurance are among the areas that are being reshaped based on the utilisation of AI, while the most recent trends are related to green finance and cryptocurrencies (Vuković et al., 2025). Analytical capabilities based on AI are also providing ways to improve environmental, social, and governance principles in the financial sector and address persistent gaps for green finance (Roy & Vasa, 2025). Moreover, the need for responsible AI that operates within a set of principles is valid across applications, including the need for transparency, explainability, and accountability in the field of business management (Dhaigude & Kamath, 2025). In related aspects, the integration of AI into strategic management practices is essential to ensure competitive advantage, uphold dynamic capabilities, and navigate emerging trends (Alhyasat et al., 2025). For competitiveness, innovative applications based on AI are providing key financial gains to economic actors. For example, innovative applications in mineral engineering involve advanced techniques for predicting and mapping mineral prospectivity, safe and autonomous systems, and anomaly detection (Yang, Feng, et al., 2025), which can boost revenues and economic payback.

With a more direct focus, application areas for the thematic focus of the TÜBİTAK Artificial Intelligence Institute on financial technologies include banking transactions, process automation, predictive analytics, anomaly detection in financial transactions, virtual assistants, authentication, recommendation engines, insurance demand forecasting, credit risk assessment, and asset portfolio management (TÜBİTAK YZE, 2025f). The main stakeholders are banks, especially public banks, insurance companies, and those working on payment systems, cryptocurrency, and blockchain (Doğrul & Yalçın, 2022). Projects together with the Turkish AI ecosystem include AI-

based solutions for financial planning, among others. The thematic focus on e-commerce technologies also focuses on AI applications that can inform the sector and more sectoral topics, such as alternative biometric recognition methods for customer acquisition (TÜBİTAK YZE, 2025d). Other example application areas include data anonymization practices and related real-world challenges.

3.5. Relevant Trends and Advances for Smart Education Technologies

In education, AI is transforming elementary, secondary, and higher education through new practices designed to understand students' learning processes, develop effective strategies, and improve their academic success (Delen et al., 2024). In the basic sciences, virtual tools for innovative pedagogical practices are being developed to support the education of skilled human resources, such as in organic chemistry and personalised learning environments for drug development (Pabuçcu-Akış, 2025). The use of digital tools in education to create interactive environments for learning continues to grow since the global pandemic, including for new teaching concepts for mathematics beyond traditional methods, with better learning results (Filiz, 2025). AI is also revolutionising lifelong learning, upskilling, and vocational education and training options in support of new job opportunities and job markets in emerging areas, which can sustain economic growth in the long term (Prasetya et al., 2025). This includes adaptive learning platforms for enhanced learning outcomes based on personalised instruction and interaction based on learner attributes, which is made possible by AI (Tan et al., 2025). At the same time, upholding learner autonomy and enabling the discovery of new academic interests remain as needs that necessitate context-sensitive solutions and applications (Peng & Li, 2025). There is a potential to increase the support of AI and data-driven decision-making in education for specific areas and cross-cutting domains, especially when ethical concerns are addressed (Abulibdeh, 2025).

Based on its role for present and future generations, the thematic focus of the TÜBİTAK Artificial Intelligence Institute on smart education technologies focuses on machine learning, natural language processing, computer vision, and deep learning in the field of education and personalized learning applications to increase the quality and efficiency of education (TÜBİTAK YZE, 2025i). In this scope, the application areas include smart learning technologies, smart classroom applications, performance and achievement measurement, smart assistants, automated, high-quality processes for education. Projects in this thematic area together with the Turkish AI ecosystem include such as AI-based engines, Large Language Models for question generation, and AI-supported personalised mentors for enabling next-generation education and creative learners.

4. Artificial Intelligence in TÜBİTAK High Technology Platforms and International Collaborations

Within the National Technology Initiative, the High Technology Platforms that are supported by TÜBİTAK provide another major venue for the development of AI technologies and solutions. Across different research programs, there are currently 20 High Technology Platforms with 252 different projects, more than 1640 researchers from universities, the private sector, and public research and development units, and over 830 scholars (TÜBİTAK, 2025b). The newest call was opened with a focus on the green transition, including climate change, clean, accessible, and safe energy supply, and sustainable smart transportation, among others (TÜBİTAK, 2024a). Based on the call, the supported platforms will be recognised among the High Technology Platforms as the newcomers. In comparison, current platforms involve an important share that focuses on medical technologies and health research, which is another area where AI advances have been making a positive impact for society. For example, robot-assisted minimally invasive surgery, rehabilitation, disease risk prediction, health management, and disease diagnosis and classification are among the research hotspots where AI is providing advances (Shi et al., 2025). In neuroscience, AI is enabling new means for diagnosing and treating neurological disorders more effectively and improving the processing of complex neural data for personalised options (Tekin & Dener, 2025).

Among the numerous platforms in medical technological and health research, the Platform related to neuronal damage-related diseases, namely NEURONPLATFORM, is developing biomarkers and advanced technological warning systems for the diagnosis, monitoring, and treatment of diseases in this area (TÜBİTAK, 2025c). Particular emphasis is placed on biomarker, biosensor, genetic, and immune-based test kits and test panels, electro-neurophysiological systems, point-of-care testing device technologies, and nanotechnological products that are linked to advanced technological warning systems. In aspects of AI, the platform is working to develop AI support systems that integrate imaging, clinical testing, and biomarker alerts. Overall, the platform brings together expertise in nanotechnology, biotechnology, sensor technologies, bioinformatics, and machine learning, involving five universities, two public R&D centers, three private-sector firms, and 28 collaborating institutions. Other important High Technology Platforms in medical technologies and health research include those on targeted therapy, biomedical products, vaccine and drug development, and restorative medicine.

Within the National Technology Initiative, these illustrative examples of High Technology Platforms are important for AI-related advances, too. For example, AI accelerates drug discovery processes and timelines, including through its utilisation for drug screening as well as the screening of chemical compounds to determine drug-

induced toxicity when integrated with large-scale datasets and omics profiles (Ajisafe et al., 2025). In addition, models based on AI have potential for enabling personalised healthcare and improving diagnostic accuracy, and their performance continues to be tested for wider applicability (Daemi et al., 2025). Multimodal AI that merges different, heterogeneous data is offering new insights in clinical settings for clinical decision support systems to improve healthcare delivery (Ardıç & Dinç, 2025). In another aspect, technological innovation based on AI and telemedicine is becoming increasingly vital for the future of health systems considering global health challenges (Hadian et al., 2025). In addition to radiology and pathology, AI has a key role in robotic surgery, including in soft tissue procedures and orthopedic applications, although more advances are necessary for these solutions to be scalable and accessible with low costs and standard operation durations (Beyaz et al., 2025). Health informatics is another research area that is benefiting from advances in AI, including through the rise of virtual reality in healthcare processes with integration of expertise across multiple disciplines (Damar et al., 2024). However, concerns about reliability, ethical aspects, and safety continue to limit the potential of AI techniques in most clinical workflows (Shool et al., 2025).

Beyond the health domain, another example is the Advanced Technologies for Sustainable Cities Platform (SÜİT) that is developing advanced technologies, including AI-based technologies, in a human-oriented and sustainable manner for the infrastructure of smart cities (TÜBİTAK, 2025d). The AI technologies relate to innovative, scalable IoT nodes for smart city technologies and AI-based advances, AI optimization algorithms, and blockchain technologies for managing real-time demands in an autonomous system for electric vehicle fleets. AI-supported control algorithms and decision-support systems for reducing building energy consumption and emissions at different scales are also developed. The platform involves three universities, a public R&D centre, private sector firms, and 10 collaborating institutions. In the area of circular economy, the LignoNANO Platform focuses on high value-added advanced nanotechnological materials from lignocellulosic biomass for a green, sustainable economy, and includes AI technologies (TÜBİTAK, 2024b). Examples may be given from a portable hyperspectral camera with high spectral resolution in spectral ranges for agricultural applications that is compatible with drones and automation systems. Here, AI and deep learning technologies are developed based on the spectrum information under different conditions. The platform involves two universities, public R&D centres, private sector firms, and 22 collaborating institutions. Yet other High Technology Platforms include those focused on batteries and advanced vehicle technologies, electronic and optical components for aviation, quantum technologies, nanotechnology, additive manufacturing, environmental technologies, solar energy technologies, and sustainable agriculture and food security.

Recognising that international cooperation accelerates scientific excellence, strengthens national capacity and ensures global competitiveness, TÜBİTAK places strategic emphasis on bilateral and multilateral partnerships in AI. As of 2025, bilateral cooperation programmes with China, Slovakia, Malaysia, Azerbaijan and Moldova specifically identify AI as a priority theme. Several other bilateral calls, including those with Malta, France, the Republic of Korea and Germany, are open to AI-focused proposals under broader digital technologies or cross-disciplinary frameworks.

Türkiye's participation in Horizon Europe, coordinated nationally by TÜBİTAK, constitutes a central component of its international strategy in artificial intelligence and advanced digital technologies. Through this framework, Turkish universities, research centres and companies collaborate with European partners on cutting-edge work in AI, robotics, advanced manufacturing, next-generation mobility, sustainable industry, and semiconductor technologies. These collaborations support work in areas such as AI-enabled circular production models, data-driven and robotics-supported sustainability applications, energy-efficient industrial optimisation, connected and autonomous mobility solutions, and the development of secure, low-power edge computing architectures, among others. Türkiye's active participation in the Chips Joint Undertaking further strengthens national capabilities in semiconductors, trusted electronics and AI-enabled embedded systems, backed by TÜBİTAK's co-funding mechanisms that facilitate broader national involvement. Through these international initiatives, Türkiye enhances its research excellence, deepens integration into European high-technology value chains, and advances strategic competencies in AI and digital sovereignty.

5. Future Outlook for Artificial Intelligence and Technology Roadmaps

Türkiye's Artificial Intelligence Roadmap aims to guide the national R&D ecosystem with the ambitious goal of surpassing global levels in AI technology (Republic of Türkiye Presidential Science Technology and Innovation Policies Board, 2021). Developed through a highly consultative process involving over 770 participants, the roadmap's strategic structure is built on three interconnected layers. The first layer outlines five key technological goals, targeting advancements in areas like high-performance deep learning, greater explainable AI, and effective modelling with limited labelled data. The second layer focuses on ten critical products and technologies essential for domestic capability, including intelligent robotics, advanced natural language processing, Turkish speech recognition, and privacy-preserving federated learning platforms. The third layer identifies 14 critical sectoral needs, prioritizing the deployment of AI solutions in vital fields such as medicine and health, energy, agriculture, and even space applications.

Following this comprehensive structure, TÜBİTAK has translated these goals into 29 specific R&D topics, which use Technology Readiness Levels (TRLs) to map out and measure the expected progress from initial concept to mature, deployable technology, thereby setting clear expectations and directing national innovation priorities. The expectations that are set forth in these R&D and innovation topics based on the Artificial Intelligence Roadmap give pace and direction to the national ecosystem. TÜBİTAK is continuing to develop technology roadmapping studies and priorities to give additional directions to the R&D and innovation ecosystem (Aydın, 2024). Taken together, these roadmap studies and prioritised research efforts not only guide the national R&D ecosystem but also strengthen Türkiye's long-term strategic capacity in artificial intelligence. They turn scientific ambition into measurable progress and provide a solid basis for evaluating the broader impacts of AI on national competitiveness and global positioning. The following section therefore turns to the strategic significance, international role, and emerging challenges of AI within the National Technology Initiative.

Türkiye's national AI ecosystem has expanded rapidly through TÜBİTAK's integrated support mechanisms, making artificial intelligence one of the country's top strategic priority areas within science, technology and innovation policy. Across ARDEB, TEYDEB, BİDEB and BİTO programs, AI-oriented activities are supported in a complementary and mutually reinforcing manner, enabling strong linkages between academic research, industrial R&D, human capital development, and public-sector innovation.

ARDEB programmes have supported a wide range of academic AI research, providing a strong scientific foundation for advances in machine learning, data science, robotics, and intelligent systems. TEYDEB, through its mandate to strengthen industrial R&D and innovation, has similarly enabled extensive AI-focused work in industry, fostering the development of AI-based products, advanced analytics solutions, and sectoral digital transformation across fields such as manufacturing, finance, agriculture, mobility, and sustainability.

BİDEB plays a pivotal role in cultivating future AI talent. Through scholarships, research fellowships, doctoral mobility schemes and young researcher programmes in areas including AI, big data, cyber security and cloud computing, it ensures a steady and qualified pipeline of experts entering academia, industry and the public sector.

Through BİTO, national AI literacy, coding skills and computational thinking are strengthened from an early age. AI-related themes, such as machine learning, algorithm design, digital twins, robotics, AR/VR and big data, are now embedded in science fairs, public-outreach initiatives and educational workshops. Numerous student projects and science talks organised across the country further demonstrate the widespread diffusion of AI awareness within society.

6. Strategic Impact, International Positioning and Challenges

AI initiatives carried out under the National Technology Initiative are delivering visible and measurable contributions to Türkiye's national objectives. These include measurable increases in the domestic production rate of critical technologies, exports of AI-enabled products, and reductions in dependence on foreign software and hardware. The expanding pool of skilled human capital, supported by TÜBİTAK programs, university-industry partnerships, and entrepreneurship initiatives, strengthens country's innovation ecosystem. The integration of national AI infrastructure such as the ARF ACC supercomputer ensures efficient use of high-performance computing resources across sectors.

At the same time, the ecosystem faces several structural challenges such as retaining qualified talent, ensuring sustainable funding for research infrastructures and maintaining international interoperability. Addressing these challenges requires close coordination between policy, regulation, and scientific excellence, underpinned by an adaptive and collaborative model of governance. In this evolving landscape, artificial intelligence has come to reresent both a horizontal enabler and a vertical strategic domain within the National Technology Initiative. Türkiye's coordinated actions across ministries, research institutes, and private sector actors are positioning the country as a regional leader in AI-centered technological independence, innovation diplomacy, and ethical digital transformation.

In summary, Türkiye's forward-looking approach to AI rests on strategic prioritisation, strong institutional coordination, sovereign computational capability, international integration, and human-centric technology governance. These elements together will shape the country's trajectory in artificial intelligence and strengthen its position within the global technological landscape.

Conclusion: Türkiye as a Hub for Advanced Technologies and Breakthroughs

As emphasized in the Twelfth Development Plan, Türkiye is on the path of becoming an attraction centre for top scientists in the region and around the world and a hub for advanced technologies, including AI. The National Technology Initiative that is integrated with these strategic national directions for high technology areas is already making leaps in progress, including through national projects, technology competitions for young human resources, dedicated programs, ecosystem calls, the TÜBİTAK Artificial Intelligence Institute, High Technology Platforms, technology roadmaps, and prioritised topics. Based on this momentum, researchers supported under the International Fellowship for Outstanding Researchers and International Fellowship for Early-Stage Researchers Programs of TÜBİTAK are also determining

their research destinations from institutions around the world to come to the country, including in the field of AI. Prior to the newest 2025 calls (TÜBİTAK, 2025a), international fellows have come to Türkiye to undertake pioneering advances in AI, machine learning, deep learning, and edge computing, as well as AI solutions for finance, climate change, drug discovery, medical treatments, and unmanned aerial vehicles. International fellows have also worked to optimise AI algorithms and provide AI-related advances in physics, predictive maintenance in power grids, radar systems, and autonomous driving.

Furthermore, numerous research projects that are based on bilateral scientific and technological cooperation agreements, as well as those under Horizon Europe, are connected to AI technologies and applications, which are expected to continue to grow in the future. Moreover, at the global stage, TÜBİTAK has taken institutional leadership in co-hosting the most recent annual conference of the Global Research Council that produced two new Statements of Principles, both involving emphasis on AI. First, the statement on Co-Creation for Addressing Global Challenges underlined the importance of leveraging emerging technologies, such as AI, to enhance co-creation processes (GRC, 2025a). Second, the statement on Research Management in the Era of Artificial Intelligence indicated both the challenges and opportunities for such practices with recommendations to public research funding and support organisations (GRC, 2025b). The achievements of the R&D and innovation ecosystem well exceed those within the country and extend to making contributions on a global scale.

These are highly promising developments as the country works to achieve the guiding vision in the Century of Türkiye based on the National Technology Initiative. Ultimately, scientific and technological breakthroughs for environmentally friendly development, resilience, production of high added-value based on advanced technology, and fair sharing of income will be made possible based on the success of the R&D and innovation ecosystem. The transformative power of AI for more competitive, resource-efficient, and sustainable economies can be enabled by targeted, collaborative approaches. In Türkiye, advances in AI technologies and solutions are being enriched with aligned strategic directions at the national level and the dedication of researchers, young human resources, and institutions within the R&D and innovation ecosystem. Together, all actors of the R&D and innovation ecosystem are working in collaboration to make the guiding vision for the Century of Türkiye a reality.

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Prof. Dr. Orhan Aydın has served as the President of the Scientific and Technological Research Council of Türkiye (TÜBİTAK) since September 2024. Prof. Aydın received his B.Sc. in Mechanical Engineering from Karadeniz Technical University in 1991. After receiving his Ph.D. in 1998, he conducted postdoctoral research and served as a visiting scholar at the University of Michigan, Ann Arbor, between 1999–2001 and 2003–2004. In 2007, he was appointed Professor of Mechanical Engineering at Karadeniz Technical University. During his academic career, he supervised numerous master's and doctoral students and served as principal investigator, researcher and scientific advisor in nationally and internationally funded research projects. His research has focused on thermodynamics, heat and mass transfer, fluid mechanics, transport phenomena in micro-electro-mechanical systems (MEMS), flow boiling, biological heat transfer, electronic cooling and energy storage. He has published more than 150 articles in international peer-reviewed journals, authored book chapters, and presented his work at numerous national and international scientific conferences. His publications have received more than 8,500 citations and have an h-index of 51. Alongside his academic career, Prof. Aydın has held several senior leadership positions in higher education. He served as Vice Rector of Karadeniz Technical University between 2008 and 2012 and as Rector of Tarsus University from 2018 to 2024, before being appointed President of TÜBİTAK in September 2024. In addition to his academic and leadership roles, Prof. Aydın has served on several national boards and advisory bodies in higher education, research and innovation. He served as Institutional Advisor to the Council of Higher Education (YÖK) (2012–2016) and as a member of the YÖK Supervisory Board (2016–2018). He also served on the Executive Board of the Technology Transfer Mechanisms Support Group (2013–2016; 2020–2023) and the Board of Directors of TÜBİTAK ULAKBİM (2022-2024). He received several national and international awards, including the METU M. N. Parlar Foundation Research Incentive Award (2007), the TÜBA Outstanding Young Scientist Award (2008), the TÜBİTAK Incentive Award (2008) and the TWAS Associate Membership Award (2009). Prof. Aydın is a Full Member of the Turkish Academy of Sciences (TÜBA). Recently, in 2025, he was appointed to the Council of Science, Technology and Innovation Policies under the Presidency of the Republic of Türkiye.