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IOT TECHNOLOGY INDUSTRY: STATUS AND DEVELOPMENT DIRECTION IN SOUTH AFRICA AND POTENTIAL FOR SMART MANUFACTURING

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Abstract: The global digital transformation era positions the Internet of Things (IoT) as a fundamental driving force for profound industrial upgrade and societal intelligent change. This paper provides a comprehensive analysis of the IoT domain, examining its evolving technological concepts, current global status, and development trends within the context of the industrial revolution. We specifically investigate technological concepts and the evolution of IoT within the context of the industrial revolution, its current global status and trends, and examine strategic development directions and key research priorities for technological innovation in South Africa's IoT sector. Based on an analysis of the scientific challenges and major issues inherent in managing massive heterogeneity and complexity (including data assets, security, and open ecological architecture), this work proposes key strategic development directions and research priorities to advance the IoT sector. The ultimate objective is to propel the industry beyond closed, vertical systems toward a broader, open, and interconnected ecosystem that effectively elevates networks from merely connecting all things to "empowering all things," realizing efficient, on–demand intelligent interconnection for potential smart manufacturing disposition and a new intelligent era in the industrial sector.

Keywords: IoT technology, IoT development direction, Status and trend, South Africa

INTRODUCTION

The "Internet of Things (IoT)" promotes digital transformation and intelligent upgrades across industries through digital mapping and smart control of the physical world [1]. Currently, IoT continues to penetrate production, public services, and social governance, bringing profound milestone changes. Global IoT connection methods are diverse.

According to IoT Analytics statistics, nearly 60% of global IoT connections rely on short-distance local-area network technologies, with Wi-Fi accounting for 31%, Bluetooth for 27%, and almost 20% via cellular network long-distance connections. Fusion and collaboration of multiple connection technologies are becoming essential trends in IoT development [2]. The arrival of the intelligent era not only drives the expansion of IoT's "connections" for all things but also reconstructs the forms of production tools and infrastructure, endowing them with new intelligent life. Through multi-domain collaboration, such as "communication-sensing-computing-control" and the development of new infrastructure, it propels the human social ecosystem from informatization to intelligence, providing the core carrier of IoT's "new quality productive forces" as a new intelligent network infrastructure for digitalization. Thus, triggers a profound reconstruction of national information technology and industrial structures.

The basic concept of IoT shifts network infrastructure from targeting people as connection objects and service goals to expanding to include all objects, encompassing people, machines, and things, as connection objects and service targets [3]. The technical philosophy of IoT relies on information network infrastructure to connect, on demand, all object-end entities (including physical and virtual objects) such as people, machines, and things located in relevant information service spaces (including industry, transportation, agriculture, cities, social life, healthcare, etc.). This enables information transmission and interaction, achieving intelligent identification, positioning, tracking, monitoring, and management to meet business needs in related service environments [4].

Furthermore, it also performs human-like knowledge acquisition, analysis, automated decision-making, and behavioral control, ultimately enabling intelligent production and services that satisfy business requirements [5]. Throughout the history of industrial development worldwide, the origin and driving force of each industrial revolution is first a revolution in infrastructure, i.e., production tools. In Industrial 1.0, the emergence of steam engines as new infrastructure production tools propelled the steam industrial revolution; in Industrial 2.0, generators as new infrastructure drove the electrification revolution; in Industrial 3.0, information networks and computers as new infrastructure fueled the informatization revolution [6].

Therefore, in the Industrial 4.0 era, marked by the on-demand, collaborative interconnection of all things in IoT scenarios, the emergence of new intelligent infrastructure as new quality productive forces' production tools will drive a new intelligent industrial revolution [7]. People, machines, things, etc., as production factors, become the acting subjects and service targets of new production tools. In traditional productive forces, laborers are the primary element, humans are the labor subjects of production tools, i.e., users, utilizers, and servers, the most active and decisive factor; but in IoT scenarios, new quality productive forces require all production factors including people, machines, things as network facility connection objects to become labor subjects and service targets of new production tools, i.e., intelligent infrastructure [8].

The present study aims to proffer a strategic roadmap and serve as a foundation for policy and investment decisions in the national IoT sector, providing a high-level overview of the Internet of Things (IoT) landscape in the Digitalisation era. It analyzes the current global status and development trends of IoT technology and its industrial applications, particularly within the context of the industrial revolution. It proposes analytical insights, strategic development directions, and key research priorities for technological innovation and the development of the IoT sector, specifically focusing on its integration in South Africa.

METHODOLOGY

This research adopts a structured method, applying the PRISMA technique to identify and evaluate recent advancements in IoT-enabled systems. A concise methodological flowchart is presented in Figure 1. Literature was retrieved from major scientific databases, including IEEE Xplore and ScienceDirect. The search was conducted using combinations of keywords such as "IoT AND technologies," "IoT technology industry," "future IoT technology," and "industrial internet of things."

The review considers only articles published from 2020 to 2025 to ensure coverage of the most recent developments in the field. Only peer-reviewed journal articles, conference proceedings, and book chapters were considered for the analysis. Furthermore, non-English articles and non-academic reports were not included in this study. After removing duplicates and applying inclusion criteria, 37 studies were analyzed.

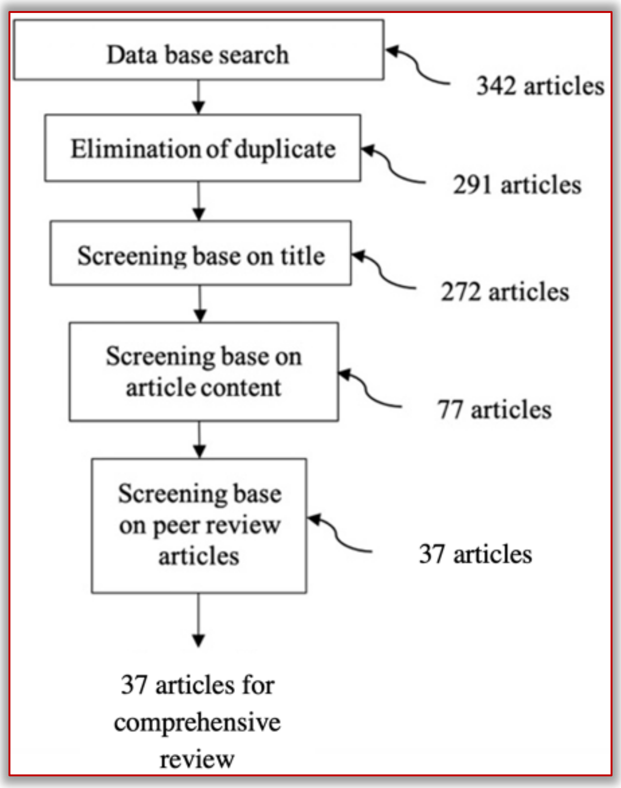

Figure 1. Outline of article selection and screening process

The remainder of the paper is categorised as follows. The development status and analysis of the IoT technology industry are reported in Section 3. Sections 4 and 5, development status and analysis of South Africa's IoT technology industry, and directions and key technologies for the future of South Africa's IoT Technology Industry, respectively. Section VI discusses the challenges to adoption. The research conclusions are presented in Section VII.

GLOBAL DEVELOPMENT STATUS AND ANALYSIS OF THE IOT TECHNOLOGY INDUSTRY

Since the concept of ambient backscatter communication systems emerged, academic researchers have conducted extensive studies in related directions. Early research focused on building prototype systems for feasibility verification and performance evaluation. Researchers have built a basic ambient backscatter communication verification system, achieving short-range communication between two passive tags and specifically designing data packet formats and carrier-sensing mechanisms. Ref. [19] proposed using two antennas at the receiver to exploit differences in received signals to cancel interference from ambient RF signals. Prototype verification results demonstrated that this method can effectively enhance system data rate and communication distance. Ref. [20] implemented the LoRa protocol using backscatter communication technology, achieving ultra-long-distance communication with very low energy consumption using commercial LoRa receivers.

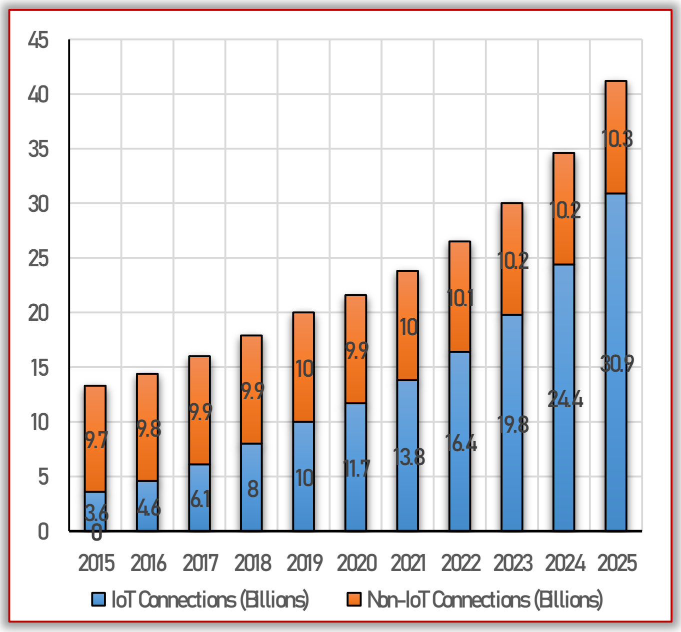

Figure 2. Prediction of IoT and Non–IoT Connections 2015 2025

US IoT Technology Industry

The US government attaches great strategic importance to IoT development, viewing it as a core driver of future industries. This stance is highlighted by a series of policies over recent years, including the Trump administration's "Fiscal Year 2022 R&D Budget Priorities" memorandum and the "US Innovation and Competition Act" [10], both of which explicitly support the IoT field. In 2022, the North American IoT market size reached 179.71 billion USD, achieving the maximum market share, and is expected to grow at a compound [11], [12] annual growth rate (CAGR) of 25.1% from 2023-2030 [11], [12].

The North American IoT market size prediction is shown in the Latest predictions, which show that global IoT spending will approach 1 trillion USD by the end of 2025. Among them, the North American IoT device market will achieve 24.5 billion USD in sales revenue in 2024 and is expected to reach 53.2 billion USD by 2030, with a CAGR of 13.5%. The security field is growing particularly rapidly, with the North American IoT security market size expected to reach 11.9 billion USD by the end of 2025, and a CAGR of 21.97% over the next five years [13], [14].

Benefiting from the rapid growth of cloud-based customer bases, IoT applications in healthcare, industrial manufacturing, and automotive industries have seen significant growth. In addition, due to the expansion of IoT-supporting devices, increased investment in technology R&D, and participation from major market players such as Google, Amazon, Microsoft, Cisco, and IBM, cloud platforms have been widely adopted in the region.

China's IoT Technology Industry

China's IoT industry has accumulated significant advantages, especially by making substantial progress in key technologies and infrastructure, such as wireless intelligent perception, sensor networks, microsensor design and manufacturing, and wireless mobile base stations [15]. As of September 2023, there are over 8,000 IoT-related enterprises nationwide, with the industry scale approaching 3 trillion yuan and continuing to grow rapidly. The basic theory and key technologies of IoT have gradually been established, with national and industry standards accelerating improvement; 249 standards have been released or are under development [16].

China's IoT industry development is generally in sync with international levels. It leads in some areas, with the industrial system becoming increasingly perfect, structure continuously optimized, and entering a key stage from high-speed growth to high-quality development. With continuous policy and technological promotion, China's IoT market is booming, with the cellular IoT terminal user base of the three major operators expanding and the IoT development space broadening.

The trend of China's IoT market size from 2020 to 2025 is in several works [1], [16], [17], [18], [19], [20], [21]. In 2020, China's IoT (US Innovation and Competition) market size reached 2.14 trillion yuan, a year-on-year increase of 10.67%; by 2022, it reached about 3.05 trillion yuan, a year-on-year increase of 15.97%. With policy support and technological improvements, the IoT market size will continue to grow, reaching 4.55 trillion yuan by the end of 2025, making it one of the fastest-growing and most promising markets globally [22].

Russia IoT Technology Industry

Russia reformulated the "National Agricultural Development Plan" in 2019, adding contents such as "agricultural product export development" and "agricultural digitalization," and formulated the "Strategy for the Agro-Industrial Complex by 2030," where the fifth strategic goal is the digital transformation of the agro-industrial complex, aiming to record all relevant information on Russia's agricultural land in a unified system by 2030 and complete the collection and analysis of 100,000 indicators [23], [24]. To this end, the country established a unified digital agriculture platform, with 75% of various supports provided to agriculture by 2024 running in digital form.

Russia has established a dedicated "Smart City" department, primarily responsible for smart city development. It has implemented pilot projects in cities such as Yekaterinburg, Samara, and Armavir, building municipal service portals for medical data analysis and other social services. IoT-related industries also include smart transportation, smart communications, smart services (healthcare, education), smart environment (buildings, charging, waste disposal), etc., all of which account for a high proportion of Russia's IoT industry's urban applications [25]. Russia's IoT industry mainly covers five key areas: industry, agriculture, cities, energy, and smart grids.

EU IoT Technology Industry

In recent years, the EU has continuously promoted the development of IoT and edge computing, moving from policy-making to a new round of strategic deepening. Since 2020, the EU has held multiple "IoT and Edge Computing" strategic seminars, initiated discussions on next-generation IoT strategies, and released the "White Paper on EU IoT Research, Innovation, and Deployment Priorities" in January 2022, setting a clear roadmap for Europe's future IoT development [26]. This not only involves frontier directions such as human-machine interaction, sustainable IoT, data valorization, edge intelligence, security and trust, and open standards, but also marks the EU's IoT development entering a new period emphasizing top-level design and innovation-driven technology implementation.

To promote IoT industry development, the EU has launched a series of measures and methods, including the "Digital Single Market" plan [27], aimed at strengthening digital technology applications and standardization to provide a better environment for IoT industry growth; simultaneously strengthening IoT privacy and security protection, issuing the "General Data Protection Regulation (GDPR)" [28], which specifies standards for personal data processing and protection to ensure healthy IoT development. The EU also provides funding support for the IoT industry, such as the "Digital Europe" program offering 10 billion euros in funding for IoT and launching the "Smart Cities Challenge" program to encourage cities to adopt IoT technology for improving urban management efficiency [29], [30], [31].

Japan IoT Technology Industry

Japan's IoT development has evolved through strategies from "e-Japan" to "u-Japan" and "i-Japan," with current core goals unified under the "Society 5.0" blueprint [32]. To advance this vision, Japan established the IoT Promotion Consortium in 2015, comprising thousands of companies. This consortium not only leads domestic technology applications and policy coordination but also actively engages in international cooperation, partnering with relevant organizations in the US and Germany. In specific actions, Japan released the "5G" plan in 2017, aiming to accelerate IoT implementation through 5G commercialization. Recent application goals focus on logistics and manufacturing, such as promoting drone truck platooning on highways and leveraging 5G's extensive connectivity to enhance factory intelligence.

Additionally, Japan highly values the security challenges arising from this, as evidenced by the release of the "IoT Security Framework" to guide the development of security systems [33]. Currently, the industries with the highest IoT market spending in Japan are assembly manufacturing, process manufacturing, government agencies, public interests, retail, and transportation. The high spending in manufacturing is due to its large share of GDP, significant government support measures, increased production throughput, and the monitoring of manufacturing processes. In addition, measures to address aging social infrastructure and complex transportation systems, continuous increases in smart grid spending, and the popularity of IoT applications in supply chains will also drive spending in these industries.

On the consumer side, individual consumer IoT spending is mainly driven by smart homes. Beyond smart homes, high-growth potential use cases include in-hospital clinical care, smart recommendations in retail stores, smart grids/meters, telematics insurance, connected buildings (smart lighting), and smart agriculture [34]. These emerging application scenarios not only expand the industrial boundaries of IoT but also provide real support for human-machine-thing connectivity and data-driven social governance under Japan's "Society 5.0" strategy.

DEVELOPMENT STATUS AND ANALYSIS OF SOUTH AFRICA'S IOT TECHNOLOGY INDUSTRY

IoT Technology Industry Development in the Gauteng

The Gauteng region, as a critical origin and industrial hub of South Africa's IoT technology, has matured, with core features of high-end technological breakthroughs and deep integration with large-scale applications. While Gauteng is the smallest by area, it is the economic powerhouse, home to Johannesburg and Pretoria, and the most densely populated in the country. It not only leads domestic technology standard formulation and innovation strategy implementation, but also continuously consolidates its leading position by strengthening its presence in high-value-added areas such as IoT system integration and vertical industry application solutions, successfully attracting many core enterprises along the industry chain to establish R&D centers and headquarters. The current characteristics of the IoT industry chain in the Gauteng region are as follows. The overall South African IoT market is projected to grow significantly, with some estimates placing the Compound Annual Growth Rate (CAGR) at over 13% in the coming years [35], [36]. This growth is heavily concentrated in and around major urban centers like Johannesburg and Pretoria (Gauteng). The innovation ecosystem is becoming increasingly perfect (as the economic and financial hub of South Africa).

The Gauteng region has strong economic vitality and high openness, with numerous universities and research institutions, providing strong support for IoT R&D and the emergence of IoT enterprises [37]. Moreover, the planned Lanseria Smart City, announced by the South African President, is a significant, long-term development set to house up to 500,000 people by 2030 and will inherently require extensive IoT infrastructure.

Evidently, the Gauteng region has built a comprehensive industrial chain support system. With a focus on R&D design and headquarters agglomeration, multinational and local technology firms, including MTN Group, Vodacom, Microsoft, IBM, Huawei, and Telkom, are actively driving the market through innovative product offerings and strategic partnerships, leading to the development and utilization of high-end manufacturing, sensors, and key components [38], [39].

This differentiated collaborative pattern forms a strong industrial agglomeration effect. Altron Digital Business and Vodacom Group, through its subsidiary IoT.nxt, are prominent examples of major companies driving IoT adoption and innovation in the region and takes the lead in domestic IoT core technology R&D, application demonstration promotion, etc., playing a leading role in national IoT technology industry innovation development, assuming the “pillar” for related industry standard formulation; initially forming an IoT industry agglomeration area with Transnet; South Africa's state-owned rail, port, and pipeline company uses an in-house Industrial IoT platform called “Iris” for container and marine craft monitoring, smart energy management, and asset tracking, thus, supports with technology innovation and market application capabilities ranking at the forefront nationally [40], [41].

IoT Technology Industry Development in the Western Cape Region

With successive policy implementations and agglomeration effects highlighted, the Western Cape region has abundant labor and market resources, ranking at the forefront in IoT enterprise numbers and industry chain completeness. Currently, the Pearl River Delta has formed a complete IoT industrial ecology, with hardware manufacturing as the foundation, core technology breakthroughs as the driving force, and diversified application scenarios as the traction. Moreover, as Cape Town is the provincial capital, the region is widely recognized as a central technology hub in Africa, offering a fertile environment for IoT development and adoption. The Western Cape boasts one of South Africa's most active and well-funded start-up scenes. This concentration of talent, venture capital, and accelerators directly supports the growth of specialized IoT companies in areas like Agri-Tech, Fin-Tech, and Health-Tech [38], [42]. This region has successfully cultivated a batch of leading local enterprises that provide independent intellectual property solutions, such as RFDigi.

At the same time, the industrial agglomeration effect is significant, gathering over 700 RFID-related enterprises from chip design (such as RFIDEA) to application services (such as Osiris Technical Systems), and attracting production and packaging centers of international giants [35]. Supported by the Technology Innovation Agency's mandate to enable and support technological innovation across all sectors of the economy to achieve socio-economic benefits for South Africa.

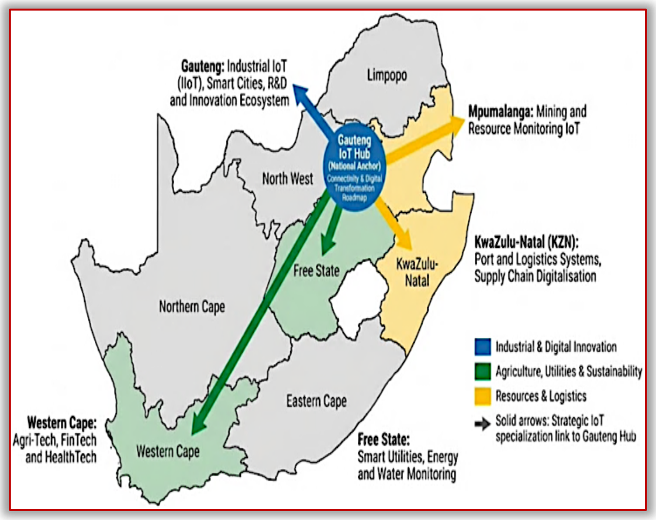

Figure 3 South Africa's IoT Provincial Specialization Map

IoT Technology Industry Development in the KwaZulu-Natal and other regions

The development status, key drivers, and applications of IoT in KZN center around the Durban-Pietermaritzburg corridor, from the ports and manufacturing industry to Agri-tech and Smart city pilot projects. The KwaZulu-Natal region has cultivated IoT at a high level, built the only IoT cluster in the national advanced manufacturing cluster, and delivered a series of major application demonstrations that informed policy support: The KZN Digital Transformation Strategy (2020-2025) [43].

Thus, forming relatively mature IoT application promotion experience and models that combine IoT, Robotics, and AI to improve service delivery, foster economic development, and enhance the social upliftment of its citizens. Overall, South Africa takes intelligent sensors, vehicle networking (City of Johannesburg), and industrial Internet as characteristic industry sub-tracks of “one perception two networks”, building a multi-level information communication application scenario open promotion system [40], [42]. Creating major application scenario pilot zones, and establishing a mechanism, through an IoT “pilot plan,” introducing IoT technology and application and competition, etc., oriented to scenario needs from application ends such as enterprises and cities, which will be inherently reliant on core IoT technologies for its design and operation, thereby recruiting and landing national technological innovation achievements.

Notably, High adoption in specialized IIoT for monitoring high-value assets in the mining and power generation sectors is recorded in Mpumalanga. Also, smart utilities for the Mangaung Metro and Logistics/Fleet Tracking are emerging in the Free State. Overall, the IoT industry outside of the 'Big Three' provinces (Gauteng, Western Cape, and KwaZulu-Natal) is highly specialized, solving challenges unique to resource management (water, energy), mining and improving agricultural yields across vast, remote areas and advancing industrial efficiency (IIoT in smart manufacturing), [20], [44].

DIRECTIONS AND KEY TECHNOLOGIES FOR THE FUTURE OF SOUTH AFRICA'S IOT TECHNOLOGY INDUSTRY

South Africa's IoT technology industry has entered a key stage, moving from scale expansion to quality improvement, from single-point breakthroughs to system integration, and from local exploration to comprehensive penetration. Overall, IoT, as a critical supporting force for the deep integration of the digital economy and real economy, is showing development trends such as accelerated infrastructure improvement, independent controllability of core technologies, deep integration of artificial intelligence, enhanced industry empowerment role, and accelerated formation of advanced clusters, becoming an important engine driving industrial upgrades and modernization of social governance.

South Africa's new digitalisation infrastructure is transitioning to a paradigm shaped by new-generation information technology, the cornerstone of the digital economy and social digital transformation, focusing on the following areas. 5G networks have characteristics of high speed, low latency, and large connections, able to meet emerging application needs such as high-definition video, virtual reality, augmented reality, intelligent driving [36]; Data centers as physical carriers for centralized storage, processing, and analysis of massive data, providing necessary data storage and computing service support for upper-layer applications [37], [41]; Artificial intelligence technology has made long strides in multiple key areas, particularly outstanding in computer vision, speech information processing, and natural language understanding, providing core technical support for intelligent applications [45], [46], [47], [48], [49], [50], [51], [52]; Fiber broadband networks can provide high-speed stable Internet access for homes and enterprises, the foundation for realizing digital life and office; General computing centers provide standardized non-dedicated computing resources, aiming to meet society's wide and diverse general computing needs; Intelligent computing centers focus on computing tasks in specific fields such as artificial intelligence, with strong parallel computing and deep learning capabilities; Blockchain technology, with characteristics of decentralization, tamper-proof, and traceability, shows broad application prospects in finance, supply chains, intellectual property, etc.; Notably, NVIDIA's presence in South Africa is rapidly expanding, focusing heavily on driving AI innovation through major partnerships with local tech firms like Altron and Cassava Technologies to build dedicated “AI Factories,” supplying GPUs, and establishing local infrastructure to which is foundational to emerging technologies like the Internet of Things (IoT) [53], [54].

The construction of new network infrastructure for IoT is an important task to achieve the strategic goals of “South Africa's digital transformation” (2025 - 2030). The strategic goal, which centers on the MyMzansi Digital Transformation Roadmap, launched in 2025, aiming to modernize government services via Digital Public Infrastructure (DPI) through four key initiatives: a unified Digital Identity, a Data Exchange Framework, a Digital Payments System, and a single Digital Services Platform [39]. Thus, aims to promote comprehensive socio-economic development through informatization and intelligent solutions. In contrast, new network infrastructure, providing informatization and intelligent new production tools, is the latest quality productive force realizing this strategic goal. It can be foreseen that South Africa's IoT industry will focus on breakthroughs in the following research directions related to the development and construction of new intelligent network infrastructure.

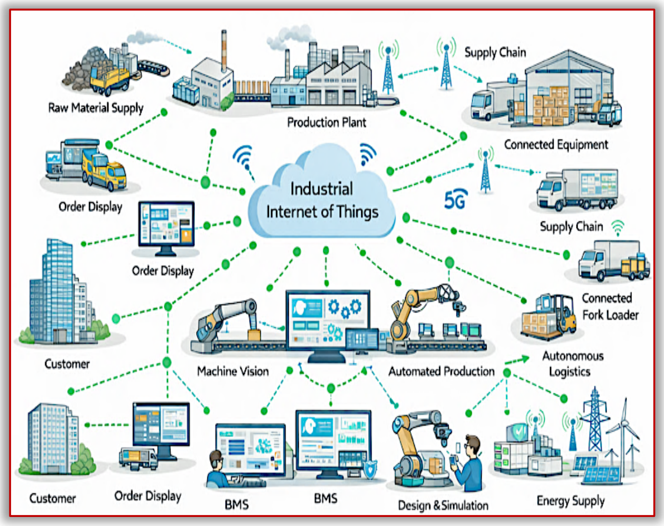

Figure 4. Smart Manufacturing Ecosystem

Identification Resolution System for IoT

Identification systems are important theoretical methods and technical means for building and describing large-scale production IoT environments. Efficiently identifying, collaborating on, and controlling various production elements will become a key scientific problem. Hence, dynamic identification systems that cover all production elements, real-time identification and recognition of each element's identity, location, status, capabilities, etc. can be performed, with resolution mechanisms used to achieve accurate positioning and intelligent control within the system. New identification systems mainly include three core components:

- object identification for assigning unique identities to physical or virtual objects, ensuring their recognizability and traceability in global networks;
- communication identification for marking communication nodes, ensuring efficient routing and secure controllability of data in transmission;
- business identification for describing and associating business processes, supporting collaboration and integration between different business links, thereby achieving underlying support for intelligent services.

Based on this new identification resolution system, corresponding network facilities can achieve on-demand resolution and dynamic scheduling of full production elements, such as people, machines, and things, thereby enabling active collaborative operation and intelligent service response.

Future Ubiquitous Perception Technology Oriented to Intelligent Interconnection of All Things

New-generation perception terminals are continuously evolving toward high precision, multi-modality, low power consumption, and battery-free directions, through frontier technologies such as environmental energy harvesting, flexible materials, and edge intelligence, achieving broader coverage, higher frequency, deeper perception of the physical world, providing basic support for on-demand data perception in ubiquitous industrial production, environmental monitoring, smart healthcare, etc., scenarios.

Intelligent IoT Security and Privacy Assurance Technology Oriented to Trusted Operation

As new IoT environments emerge with ubiquitous terminals, open scenarios, and data flows, security systems are evolving from traditional boundary protection to active immunity and dynamic trusted domains and fusing key technologies such as zero-trust architecture, lightweight terminal authentication, federated privacy computing, and AI-driven threat perception, building integrated dynamic security defence systems covering terminals, edges, networks, and platforms, achieving trusted identities, traceable behaviors, usable but invisible data security goals, providing continuously reinforced security resilience and compliant reliable data circulation capabilities for high-sensitive scenarios such as critical infrastructure, industrial production, life health.

Three-Dimensional Spatial Intelligent Network Systems Supporting Low-Altitude Economy

Low-altitude intelligent networks are relying on multi-technology fusion, such as 5G-Advanced integrated communication-sensing, low-orbit satellite communication, and radar perception, to build a collaborative three-dimensional airspace-ground network infrastructure. This system supports diverse scenarios such as logistics drone cross-domain delivery, urban air mobility, and air-space-ground integrated collaborative perception through intelligent scheduling and full-domain perception capabilities.

At the communication level, 5G-Advanced base station endogenous perception functions can achieve comprehensive identification and trajectory tracking of low-altitude targets; at the control level, through cloud-network collaboration and AI dynamic planning, they can enhance airspace resource utilization efficiency and flight safety. This system not only provides “dual-use for normal and emergency” minute-level intelligent response capabilities for scenarios such as urban governance and emergency response, but also lays the foundation for large-scale, safe development of the low-altitude economy.

These development trends and technology research directions outline the grand blueprint for the future development of IoT technology and industry, enabling South Africa always to grasp the initiative and commanding heights in regional/Pan-African technology and industry competition, and to lead strategic development directions for the future IoT technology industry and the actualization of smart manufacturing.

The illustrated smart manufacturing ecosystem (Figure 4) highlights how the Industrial Internet of Things (IIoT) serves as a central enabler for the future of South Africa’s IoT technology industry, integrating production plants, supply chains, energy systems, logistics, and customers through high-speed connectivity and data intelligence in a manufacturing ecosystem. It reflects key directions such as Industry 4.0 adoption, 5G-enabled communication, AI-driven inspection, digital twins for design and simulation, and smart energy management using renewable sources.

For South Africa, these technologies are critical to improving industrial productivity, strengthening local manufacturing, enhancing supply chain resilience, supporting energy transition goals, and driving inclusive economic growth by fostering skills development, innovation, and scalable digital infrastructure across key industrial sectors.

CHALLENGES TO IOT ADOPTION

- Load Shedding and Energy Availability: chronic power outages still disrupt the connectivity and reliable operation of many IoT devices and edge computing nodes, forcing operators to invest in battery- and solar-powered microsites.
- Digital Divide: the need for IoT solutions that address connectivity and service delivery in informal settlements.
- Governance and Regulatory Framework: the need for robust, standardized security protocols and a clear, IoT-specific data regulation framework, which raises concerns about data privacy and security.
- Skills Shortage: shortage of skilled talent in IoT development.
- Connectivity Divide: noticeable lag in internet coverage compared to global averages, particularly in remote rural areas, which limits the scope of province-wide IoT solutions.

To systematically address the above challenges, the government of South Africa needs to strengthen overall coordinated planning, build sustainable competitive advantages, and coordinate the integrated construction of IoT infrastructure.

Accelerate the integration of IoT infrastructure across different scenarios, accelerate collaborations across various network infrastructures, meet new scenario needs such as communication-sensing interconnection, intelligent transportation, and smart industry, and promote network infrastructure integration evolving toward air-space integration. Furthermore, systematically plan IoT security development. Top-level design of overall IoT security protection frameworks and systems accelerate R&D and the application of lightweight protection technologies across the hardware, firmware, and application software layers, with terminal security oriented to market demands, combined with policy guidance and industry norms. Additionally, strengthen the management and application of data assets.

Standardize management of IoT data assets, clarify management details from data collection, storage, processing, and transmission links to data mining, pattern recognition, and predictive analysis, complete chains, unblock data circulation between information communication enterprises and platform enterprises, improve data transaction exchange mechanisms, and promote the full release of data element resource value.

CONCLUSION

Increasing IoT technology industry development demands and application-led new intelligent infrastructure construction are becoming important driving forces, propelling social forms and industrial ecology to accelerate intelligent changes. With the deep fusion of digital technology and the real economy, an enormous demand for on-demand, intelligent connections among all things arises in intelligent social development.

IoT technology industry development and applications are evolving from past local, closed vertical systems to broader, open, interconnected ecological architectures. Notably, the accelerated fusion of artificial intelligence and IoT is leading profound changes in intelligent infrastructure construction, elevating networks from merely connecting all things to "empowering all things," and achieving efficient on-demand interaction and intelligent interconnection between people, machines, and things, marking IoT technology industry development as it steadily marches toward the intelligent new era.

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