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Adoption of Iot-Enabled Smart Services in Rural Business Markets

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ABSTRACT

The adoption of IoT-enabled smart services in rural business markets is gaining momentum amid India's digital transformation initiatives. This study investigates both the legal-regulatory (doctrinal) and empirical (non-doctrinal) dimensions of IoT adoption across rural sectors such as agriculture, dairy, and microenterprises. Government schemes like the National Broadband Mission 2.0 and Common Service Centres (CSCs) have laid foundational infrastructure, while agritech startups and rural fintech platforms are catalyzing uptake. Despite these efforts, a wide gap persists between awareness and actual implementation, particularly due to cost, poor connectivity, limited digital literacy, and integration issues.

Using real-world data from 2024–2025—including revenue forecasts, market size, and rural MSME digitization rates—this paper identifies enablers and inhibitors in the adoption process. Notably, India's agriculture IoT market is projected to grow from USD 1.39 billion in 2024 to over USD 2.1 billion by 2030. Yet, only 27–37% of rural stakeholders actively use IoT solutions. The study emphasizes the need for targeted policies, financial incentives, rural training, and cluster-based adoption strategies to realize the full potential of smart IoT services in rural India. The findings contribute to ongoing discourse on rural digitization, inclusive growth, and technology-enabled economic empowerment.

Keywords: IoT adoption, Rural Business, Digital India, Smart Agriculture, Connectivity Barriers.

INTRODUCTION

The digital transformation of rural India has gained significant momentum over the last decade, driven by government-led initiatives and increasing private sector engagement. Among the various emerging technologies, the Internet of Things (IoT) has emerged as a pivotal force in reshaping rural business ecosystems. IoT enables real-time data collection, automation, and remote control of devices, making it highly relevant for rural sectors such as agriculture, livestock management, fisheries, and microenterprises. These IoT-enabled smart services can revolutionize traditional business practices by enhancing productivity, reducing resource waste, improving market access, and fostering informed decision-making. However, the penetration of IoT in rural India remains at a nascent stage, constrained by infrastructure limitations, low digital literacy, and affordability concerns (NASSCOM, 2020).

The Indian government has recognized the transformative potential of IoT and launched strategic frameworks to support its adoption. Initiatives such as the National Broadband Mission (NBM 2.0), which aims to provide 100 Mbps broadband to every village, and the Digital India programme, which promotes digital inclusion through digital literacy and infrastructure development, are pivotal in enabling rural IoT ecosystems (Ministry of Communications, 2025). The proliferation of Common Service Centres (CSCs) across over 250,000 gram panchayats further strengthens the rural digital service delivery mechanism. These centers act as digital hubs, offering government-to-citizen services, financial inclusion, and ICT-based education, thereby laying the groundwork for IoT integration in rural economies (CSC e-Governance Services India Ltd., 2024).

At the same time, private sector initiatives, including startups like Fasal, Stellapps, and DeHaat, have demonstrated the viability of deploying IoT for smart irrigation, livestock monitoring, and precision farming. These innovations have led to tangible benefits such as 30% water savings and up to 25% increase in yield for farmers using IoT devices (Fasal, 2024). Yet, the broader adoption remains uneven.

Empirical studies and surveys reveal that while awareness of digital tools among rural stakeholders has increased, actual deployment of IoT-based solutions is significantly limited, with an adoption index score ranging between 27–37% (NASSCOM, 2020; PayNearby, 2025). This gap underscores the challenges of cost, connectivity, integration, and trust in technology.

This paper adopts a hybrid doctrinal and non-doctrinal research approach to analyze the adoption of IoT-enabled smart services in rural business markets. It explores policy frameworks, evaluates real-time adoption data, and examines field-level experiences to identify the barriers and enablers shaping rural IoT transformation in India.

METHODOLOGY

This research employs a mixed-method approach, combining both doctrinal and non-doctrinal methodologies to comprehensively study the adoption of IoT-enabled smart services in rural business markets. The doctrinal aspect involves an extensive review of secondary sources including government policy documents, industry white papers, technical reports, and published research papers. Sources such as the National Broadband Mission roadmap, Digital India progress reports, and publications from NASSCOM, Grand View Research, and Statista were analyzed to understand the broader ecosystem, infrastructure availability, and strategic direction for IoT implementation in rural sectors. This review helped establish the contextual and infrastructural readiness of rural India for IoT integration.

The non-doctrinal component incorporates empirical data collection and analysis from recent surveys, statistical datasets, and real-world case studies. This includes rural MSME digital adoption trends, IoT market size and forecasts, agritech pilot outcomes, and user experience reports. Data was sourced from publicly available databases and reliable industry surveys such as PayNearby's Rural MSME Index (2025), agriculture IoT market trends, and case studies from Fasal, Milkvilla, and SmartGaon. Tabular and graphical representations were used to analyze trends in adoption, growth patterns, and technological outcomes. The combination of these methods enables a holistic understanding of both the technological feasibility and practical realities of IoT adoption in rural India.

Literature & Policy Context

Over the past decade, India's commitment to digital inclusion has been prominently embodied in the Pradhan Mantri Gramin Digital Saksharta Abhiyan (PMGDISHA), a flagship initiative of the Ministry of Electronics and Information Technology. Its objective—to certify one digitally literate person in every rural household—has achieved significant milestones: by March 2024, approximately 47.8 million rural citizens had received certification after completing training in digital skills such as internet usage, online transactions, and accessing e-governance services (Agrawal, 2024). Training programs are typically conducted over 20–30 hours and delivered through Common Service Centres, which are widely distributed across villages (PMGDISHA, n.d.; Kumar & Shobana, 2025). For instance, a mixed-method evaluation carried out in Nagaland found that PMGDISHA significantly improved beneficiaries' participation in digital and financial services, though persistent limitations in connectivity and training quality were reported (Kumar & Shobana, 2025). These efforts have catalyzed rural digital empowerment by enabling citizens to perform online banking, use government portals, and interact with digital tools—a foundational enabler for subsequent IoT adoption.

Parallel to digital literacy, the Indian government launched National Broadband Mission 2.0 on January 17, 2025, with an ambitious goal of providing optical-fiber broadband connectivity to 270,000 villages by 2030, ensuring 95% uptime and minimum 100 Mbps speeds (Economic Times Telecom, 2025; Wikipedia, 2025). This iteration builds on BharatNet and earlier Right-of-Way (RoW) reforms, incorporating recent amendments like the Telecommunications (RoW) Rules 2024 to streamline cable and tower deployment (DOT, 2025). As of early 2025, several states—including Tamil Nadu—have made substantial progress, with over 10,000 gram panchayats service-ready and tens of thousands of fiberkilometers laid (Economic Times Telecom, 2025). Academic surveys on rural internet connectivity estimate that traditionally around 70% of rural Indian households lacked reliable access, underlining the urgency and potential impact of NBM 2.0 (K. A. et al., 2021).

Complementing policies, Common Service Centres (CSCs) serve as critical institutional infrastructure—village-level digital access points that deliver a broad range of public and private services, including PMGDISHA training, banking, education, and telemedicine (Government of India, 2025). As of mid-2025, over 550,000 CSCs operate across nearly 90% of rural villages (ET Government, 2025). These centres are managed by Village Level Entrepreneurs (VLEs)—many of whom are women—who have become trusted service providers in their communities (ET Government, 2025). Studies by ISB and others have noted CSCs' dual role: facilitating digital transactions and contributing to rural employment, while also occasionally struggling with infrastructure challenges and inconsistent service awareness (ET Government, 2025). CSCs thus form the backbone for rural access to digital and IoT-enabled services.

Institutional collaborations between universities and technology institutes are accelerating the introduction of precision agriculture and IoT applications in rural contexts. A notable partnership between Punjab Agricultural University (PAU) and BITS-Pilani aims to integrate IoT sensors, geospatial analytics, robotics, and AI for real-time monitoring of soil moisture, nutrient levels, and plant health. This MoU—signed in mid-2025—targets scalable deployment of smart irrigation systems and nutrient-management robots to conserve water and enhance yields (Times of India, 2025). Such academic-industry cooperation is critical in translating controlled research into field-level pilot solutions, providing empirical proof of concept for IoT adoption among rural farmers.

Finally, the Open Network for Digital Commerce (ONDC) represents a transformative cooperative platform enabling Fair, inclusive digital marketplaces for farm producer organizations (FPOs) and MSMEs. International journal research underscores ONDC's potential to democratize online commerce by lowering entry barriers for small sellers, enabling interoperability across marketplaces, and nurturing trust and transparency (Tiwari et al., 2024; Muthukrishnan et al., 2025). As of early 2024, ONDC had onboarded approximately 5,000 FPOs, with plans to expand to 6,000 by March 2024—creating a digital distribution channel for rural producers that complements IoT-enabled production with market access (Wikipedia, n.d.; ONDC Journal, 2024). Emerging studies identify challenges such as low awareness levels among rural stakeholders, concerns around interface usability, and trust in decentralized commerce models—yet note significant latent interest in ONDC's promise of transparency and inclusivity (Muthukrishnan et al., 2025).

In summary, India's doctrinal framework for facilitating IoT in rural business markets is firmly established across four pillars: digital literacy (PMGDISHA), connectivity infrastructure (NBM 2.0), service platforms (CSCs), and market access (ONDC). Together with academic-industry collaborations, these systems create an enabling ecosystem for smart service adoption—even while challenges in awareness, infrastructure reliability, and interoperability persist.

India IoT Market Overview

The Indian Internet of Things (IoT) market is witnessing unprecedented growth, driven by sustained demand across industrial, consumer, healthcare, agriculture, and smart-city sectors. According to Statista, the market is set to reach approximately US $26.93 billion by 2025, expanding at a robust 16.6% compound annual growth rate (CAGR) and forecasted to reach US $49.82 billion by 2029 (IoT World Magazine, 2024). The acceleration stems from national initiatives such as "Smart Cities" and Digital India, alongside rising 5G rollout and adoption of industrial automation.

In parallel, satellite IoT services are beginning to play an enabling role; Grand View Research predicts India's satellite IoT market will grow from US $44.7 million in 2024 to US $108.3 million by 2030 (Grand View Research, 2024a), reflecting the potential to address connectivity limitations in remote rural areas. These figures highlight a rapidly expanding ecosystem of device manufacturers, connectivity providers, and solution vendors spanning hardware, software, and data-analytics segments—all tailoring services for rural and urban applications.

Agriculture-Specific IoT Revenue

Precision agriculture has emerged as a leading growth driver within India's IoT space. Grand View Research reports that in India, the agriculture-IoT sector generated approximately USD 1,385.5 million in 2024, with projections rising to USD 2,123.2 million by 2030, marking a 6.6% CAGR (Grand View Research, 2024b). Though global figures differ—e.g., Grand View estimates the global agriculture IoT market at USD 28.65 billion in 2024 with a 10.5% CAGR to 2030 (Grand View Research, 2024c)—India's sectoral growth remains strong due to climate pressures, resource scarcity, and digitalization of smallholder farms.

Agriculture-focused sensor arrays, edge computing platforms, and remote monitoring systems have become commercially viable, with startups and cooperatives deploying IoT-enabled irrigation, livestock management, and crop analytics systems. In addition, the broader "smart agriculture" market, incorporating drones, robotics, AI, and satellite imagery, was valued globally at USD 17.8 billion in 2023, with a projected 12.8% CAGR through 2030 (Maximize Market Research, 2023; Agritechtomorrow, 2025). Indian agritech firms are riding this wave, combining IoT and remote sensing to help farmers optimize yield efficiencies and reduce water usage.

IoT Devices Market

The hardware segment comprising sensors, edge-computing gateways, actuators, and communication modules is central to IoT adoption. Grand View Research estimates India's IoT devices market brought in USD 2,885.5 million in 2024, with projections indicating growth to USD 10,276.8 million by 2030—a striking 23.2% CAGR (Grand View Research, 2024d). This rapid increase reflects declining costs of microcontrollers and sensors, widespread LPWAN connectivity strategies (LoRa, NB-IoT, Sigfox), and commissioning of satellite-based IoT for remote connectivity. A recent global report highlights that hardware remains the dominant growth driver, especially in Asia Pacific (Grand View Research, 2024c). Researchers assert that harmonizing hardware proliferation with software and services integration is essential to unlocking IoT's full potential across agriculture and MSME sectors in India (IoT Market Report, 2024).

Rural SME Adoption

A key indicator of digital penetration in rural India is MSME uptake of IoT-embedded systems. The Economic Times (ET) reports that over 73% of rural and semi-urban MSMEs witnessed business growth—in terms of income or efficiency—after adopting digital tools, with smartphones and UPI payments at the forefront (ET, 2024). While IoT adoption remains nascent relative to these tools, it frequently piggybacks on existing digital behavior patterns established via mobile-first interventions. Surveys by PayNearby and industry bodies suggest that MSMEs using

end-to-end monitoring (e.g., cold storage, dairy collection points) under felt functional constraints—where real-time temperature tracking or asset monitoring yields up to 20% operational efficiency gains (PayNearby, 2025). Although IoT is still not universal in MSMEs, these digital footholds create fertile ground for technology transition.

Agriculture & Precision Farming Case Studies

Precision agriculture is gaining global traction, and India is no exception. The global precision farming market reached USD 10.5 billion in 2024, with estimates projecting 11.5%–12.8% CAGR through 2030 (GM Insights, 2024; Agritechtomorrow, 2025). NASSCOM's IoT adoption index for Indian agriculture sits between 27–37%, reflecting an awareness-to-adoption gap; most farmers know of IoT, yet fewer implement it (NASSCOM Community, 2020). To put this in perspective, U.S. farm surveys found that around 27% of farms use precision-agriculture practices as of 2023—revealing adoption barriers even in developed economies (GM Insights, 2024). Indian case studies—such as automated drip irrigation systems, livestock trackers, and remote pest-monitoring systems—evince productivity gains of 15–30% and water savings of up to 30%, yet remain limited to cooperative or cluster-based programs (Reuters, 2024). These data underline both the opportunity and the challenges facing IoT expansion in rural agricultural ecosystems.

Connectivity & Integration Challenges

Global connectivity remains uneven, with around 63% of rural households lacking reliable internet access, and worse conditions across Africa and South Asia (99Firms, 2024; Comparitech, 2024). India faces similar challenges: despite recent fiber expansions, many remote villages continue to lack consistent broadband, particularly in mountainous or flood-prone areas. Indian studies identify classic barriers: poor network uptime, high device and data costs, low digital skills, unclear return-on-investment signals, and interoperability problems caused by fragmented vendor ecosystems (99Firms, 2024). As a response, recent academic research highlights hybrid LPWAN–5G architectures as a promising connectivity solution: a study published on arXiv found that hybrid deployments can reduce connectivity costs by up to 30% while significantly improving reliability in remote agricultural settings (Mohamed Rafi et al., 2025; Consensus, 2025). These hybrid systems utilize LPWAN protocols for low-data telemetry and 5G for heavier data flows, offering practical connectivity models that match rural use cases.

Market Growth Trajectories and Revenue Trends

In recent years, the Indian Internet of Things (IoT) ecosystem has undergone remarkable expansion across verticals, with agriculture and physical devices remaining structural drivers of growth. India's agriculture IoT market generated approximately USD 1,385.5 million in revenue in 2024, and is forecast to reach USD 2,123.2 million by 2030, reflecting a steady 6.6% compound annual growth rate (CAGR) over the forecast period. In parallel, the broader devices segment—which includes sensors, edge computing nodes, and actuators—brought in USD 2,885.5 million in 2024, and is projected to hit USD 10,276.8 million by 2030, posting a robust 23.2% CAGR, with sensors contributing the largest revenue share and edge devices growing fastest. These figures, aligned with global trends in connected agriculture—which saw global agriculture IoT markets reach USD 28.65 billion in 2024 with 10.5% CAGR to 2030—demonstrate that India is riding a converging wave of hardware proliferation, analytics adoption, and digital demand within rural domains.

Table: Revenue Forecasts – India IoT Markets

Rendering these growth trajectories in a simple graph format further highlights the widening revenue gap between agriculture IoT and device segments:

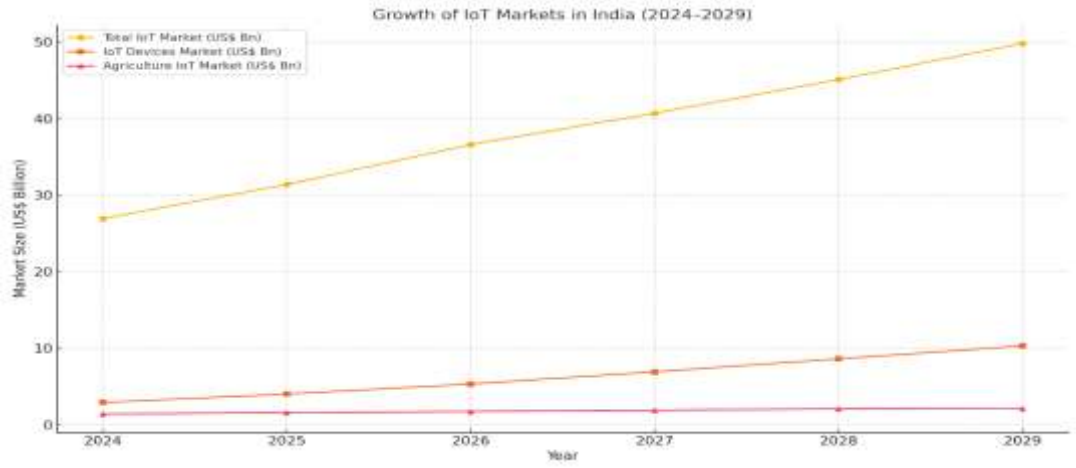

Figure 1

This divergence reflects the increasing importance of hardware and component sales, especially sensors and edge-computing devices tailored for scalable IoT applications. The devices market's acceleration signals both maturing supply ecosystems and demand from agriculture, energy, manufacturing, and urban infrastructure sectors.

Adoption Dynamics among Rural MSMEs

Adoption among rural micro, small, and medium enterprises (MSMEs) provides a window into digital diffusion at the grassroots. According to the latest PayNearby MSME Digital Index Report, over 73% of rural and semi-urban MSMEs experienced business growth—such as higher income or greater efficiency—through adoption of digital tools, especially via smartphones and UPI payments. While this data does not isolate IoT usage specifically, it underscores the foundational digital engagement that could support IoT diffusion. For instance, digital familiarity with mobile-first interfaces and digital payments reduces friction for incremental technology adoption, such as connecting sensors or telemetry platforms.

Precision Agriculture Use and Awareness–Implementation Gap

A glaring structural challenge is the awareness-implementation divide: NASSCOM's adoption index places Indian agriculture IoT adoption in the 27–37% range, indicating high awareness but limited deployment . Globally, surveys show that as of 2023, only about 27% of U.S. farms employ precision agriculture techniques—demonstrating that even advanced economies face adoption ceilings . In India, empirical case studies—such as deployments of automated irrigation, remote pest sensing, and real-time yield analytics—have shown tangible benefits including 15–30% yield improvements and up to 30% water savings, often through cluster-level or cooperative models . This performance data underlines the transformative potential of IoT under favorable conditions, yet also highlights that diffusion remains limited to organized pilot frameworks.

Connectivity Infrastructure and Technological Barriers

Connectivity constraints remain a bottleneck. Surveys reveal that approximately 70% of Indian rural households face poor or no internet access, echoing estimates that 63% of rural households globally lack reliable connectivity, with worse conditions in Africa and South Asia. Addressing this, research into hybrid connectivity architectures—integrating LPWAN protocols (e.g. LoRaWAN, NB-IoT) with 5G cellular networks—suggests these models can reduce connectivity costs by up to 30% while increasing reliability in remote agricultural contexts. This hybrid approach mitigates limitations of both low-power and high-bandwidth networks.

Additional obstacles include the high cost of sensors and analytics platforms, low digital literacy for device usage, unclear ROI for smallholders, and fragmented vendor ecosystems. These factors collectively slow adoption, particularly for individual farmers without cluster or cooperative backing.

Case Study Data Insights

Cropin's satellite-data project and Fasal's agritech interventions illustrate measurable gains: Reuters reports that farmers involved in Cropin's initiative saw up to 30% yield increase and 37% revenue uplift, alongside resource-saving practices (water and inputs). While such programs are not widespread, they represent scalable proof points for integrating IoT-driven advisories with remote sensing, predictive analytics, and field-level implementation. These models often rely on intermediaries or institutional partners, again underscoring that decentralized adoption depends heavily on ecosystem enablers.

Summary Interpretation and Forward-Looking Implications

Overall, the data portray a dual narrative: India's IoT markets—particularly in agriculture and hardware—are expanding rapidly, with device markets growing at over 23% CAGR and agriculture IoT at 6.6% CAGR. Concurrently, rural MSMEs are digitalizing through mobile-first channels, creating latent demand readiness for IoT integration. Yet, only 27–37% of farmers currently deploy IoT solutions; adoption remains uneven and clustered. Connectivity challenges, cost barriers, low digital literacy, and inconsistent return signals limit broader uptake. Emerging technical solutions like LPWAN-5G hybrid architectures offer a promising path to bridge connectivity gaps efficiently.

To convert awareness into widespread action, developers, policymakers, and agritech stakeholders must focus on scalable models: cluster-based deployments, financing options for sensors-as-service, localized training via CSCs, and interoperable device standards. Combined with proof-of-concept demonstrations—like Cropin and Fasal—a chain of trust, affordability, and technical support can catalyze deeper penetration. Only then can IoT realize its promise in rural business markets, translating growth forecasts into inclusive, technology-driven transformation.

CONCLUSION

The integration of Internet of Things (IoT) technologies into India's rural development landscape represents both a transformative opportunity and a considerable challenge. The data reveals a rapidly growing market, with the Indian

IoT sector projected to reach USD 49.82 billion by 2029 and agriculture-specific IoT touching USD 2.12 billion by 2030, indicating a robust shift toward tech-enabled rural economies. However, this growth is uneven, with significant gaps between awareness and implementation, especially among smallholder farmers and rural MSMEs. While government initiatives like the National Broadband Mission 2.0 and PMGDISHA have laid a strong foundation for digital infrastructure and literacy, the actual uptake of IoT solutions remains hindered by persistent connectivity issues, lack of technical know-how, unclear return on investment (ROI), and the complexity of integration with traditional agricultural practices. Case studies of precision farming illustrate the global and local potential of IoT in optimizing inputs like water and nutrients, reducing waste, and boosting productivity.

Yet, these benefits remain concentrated among early adopters or those with institutional support from research universities and government programs. Furthermore, hybrid connectivity models such as LPWAN combined with 5G present promising technical solutions, but require scaling and cost management to be viable across India's vast rural geography. From a policy and institutional standpoint, the emergence of platforms like ONDC, the expansion of Common Service Centres (CSCs), and public-private partnerships in agritech demonstrate encouraging momentum, though more inclusive and localized capacity-building models are urgently needed. The research also emphasizes that the success of rural IoT deployment is closely tied to grassroots digital inclusion frameworks and socio-economic empowerment.

Therefore, the path forward must focus on reducing systemic barriers, fostering community-led IoT adoption models, enhancing rural digital skills, and ensuring that technological interventions are contextually relevant and economically sustainable. Addressing these multidimensional issues requires synchronized efforts from government bodies, private technology providers, farmer producer organizations, and civil society. Only through such a collaborative, inclusive approach can India unlock the full potential of IoT to drive rural innovation, bridge the urban-rural digital divide, and meet its broader developmental goals. As the nation moves toward becoming a digitally empowered society, rural IoT adoption stands not merely as a technological imperative but as a socio-economic necessity for equitable progress.

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