



**POLITECNICO**  
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE  
E DELL'INFORMAZIONE

# The Internet of Things startups: business models and overview of the offer

TESI DI LAUREA MAGISTRALE IN  
FOOD ENGINEERING  
INGEGNERIA ALIMENTARE

Author: **Ruslan Kostin**

Student ID: 10848197

Advisor: Angela Tumino

Co-advisor: Camilla Scarpino

Academic Year: 2024-25



# Abstract

The Internet of Things (IoT) is transforming industries by enabling interconnected devices to collect, analyze, and exchange data, fostering efficiency, innovation, and new business opportunities. This thesis explores the dynamic landscape of IoT startups, focusing on their business models, market positioning, and key challenges. It investigates the predominant business models adopted by IoT startups, their market offerings, and the obstacles they face in an evolving ecosystem.

The research employs a mixed-method approach, combining quantitative market data analysis with qualitative insights from case studies and industry expert interviews. Findings reveal that IoT startups primarily operate under three business models: subscription-based services, data monetization strategies, and hardware sales, with many adopting hybrid approaches to enhance revenue diversification. These startups cater to various sectors, including smart cities, healthcare, industrial automation, and agriculture, providing solutions ranging from consumer-oriented smart home devices to enterprise-grade predictive maintenance tools.

Despite the promising market opportunities, IoT startups face significant challenges such as cybersecurity risks, interoperability issues, and regulatory constraints. However, emerging trends in artificial intelligence, edge computing, and sustainability-driven IoT solutions present avenues for growth. The study underscores the importance of strategic partnerships, robust security frameworks, and standardization efforts in ensuring the long-term success of IoT startups.

The findings offer valuable insights for entrepreneurs, investors, and policymakers, highlighting the key drivers of success in the IoT startup ecosystem and providing a roadmap for future developments.

**Keywords:** Internet of Things (IoT), IoT startups, business models, market analysis, smart devices, data monetization, innovation.

## Abstract in italiano

L'Internet of Things (IoT) sta trasformando le industrie consentendo ai dispositivi interconnessi di raccogliere, analizzare e scambiare dati, promuovendo efficienza, innovazione e nuove opportunità di business. Questa tesi esplora il panorama dinamico delle startup IoT, concentrandosi sui loro modelli di business, il posizionamento sul mercato e le principali sfide. L'analisi si focalizza sui modelli di business predominanti adottati dalle startup IoT, le loro offerte di mercato e gli ostacoli che affrontano in un ecosistema in continua evoluzione.

La ricerca utilizza un approccio misto, combinando l'analisi quantitativa dei dati di mercato con approfondimenti qualitativi derivati da casi studio e interviste con esperti del settore. I risultati rivelano che le startup IoT operano principalmente secondo tre modelli di business: servizi in abbonamento, strategie di monetizzazione dei dati e vendita di hardware, con molte che adottano approcci ibridi per diversificare le entrate. Queste startup si rivolgono a diversi settori, tra cui smart cities, sanità, automazione industriale e agricoltura, offrendo soluzioni che spaziano dai dispositivi smart per la casa a strumenti avanzati per la manutenzione predittiva in ambito aziendale.

Nonostante le promettenti opportunità di mercato, le startup IoT affrontano sfide significative, tra cui rischi legati alla sicurezza informatica, problemi di interoperabilità e vincoli normativi. Tuttavia, le tendenze emergenti in ambito di intelligenza artificiale, edge computing e soluzioni IoT orientate alla sostenibilità offrono nuove prospettive di crescita. Lo studio sottolinea l'importanza delle partnership strategiche, di solidi framework di sicurezza e degli sforzi di standardizzazione per garantire il successo a lungo termine delle startup IoT.

I risultati forniscono approfondimenti preziosi per imprenditori, investitori e policymaker, evidenziando i principali fattori di successo nell'ecosistema delle startup IoT e offrendo una roadmap per i futuri sviluppi del settore.

**Parole chiave:** Internet of Things (IoT), startup IoT, modelli di business, analisi di mercato, dispositivi smart, monetizzazione dei dati, innovazione.

# Contents

<b>Abstract</b> .....	<b>i</b>
<b>Abstract in italiano</b> .....	<b>ii</b>
<b>Contents</b> .....	<b>iii</b>
<b>Introduction</b> .....	<b>1</b>
<b>1 The Internet of Things</b> .....	<b>3</b>
1.1. Smart Objects .....	3
1.2. Smart Networks.....	5
1.3. The Internet of Things Architecture .....	6
1.4. Technology Clusters .....	9
1.5. The Internet of Things Application Fields.....	10
1.6. The Market Landscape .....	13
1.7. The Internet of Things Startups.....	16
1.7.1. Emerging Trends .....	19
<b>2 Objectives and methodologies</b> .....	<b>23</b>
2.1. Objectives.....	23
Question 1: What is the current state of startups operating in the IoT sector? .....	23
Question 2: What business models are IoT startups favoring? .....	24
2.2. Methodological Approach: Literature Review and Interviews.....	24
2.2.1. Literature Review .....	25
2.2.2. Census .....	25
<b>3 Database</b> .....	<b>27</b>
3.1. Key Insights from Data Analysis .....	28
3.1.1. Industry Trends: IoT Application Areas and Technology Clusters.....	28
3.1.2. Yearly Distribution of IoT Startup Foundations.....	31
3.1.3. Business Model Segmentation in IoT Startups .....	34
3.1.4. Geographical Trends: Regional and Country-Level Distribution.....	38
3.1.5. Funding and Growth Patterns.....	42
3.1.6. Acquisition Trends: Industry and Regional Insights .....	43
<b>4 Business models for the Internet of Things Companies</b> .....	<b>47</b>

4.1.	MOP Model.....	47
4.2.	DNA Model.....	48
4.3.	Value Net Model .....	49
4.4.	Business Model Canvas.....	49
4.5.	2x2 Matrix Dimension Model.....	50
4.6.	Three-Dimensional Model .....	51
4.7.	Analysis of IoT Startups Using Business Models .....	51
4.7.1.	Business Model Distribution .....	52
4.7.2.	Regional Analysis of Business Models.....	54
<b>5</b>	<b>Conclusion.....</b>	<b>61</b>
5.1.	Limitations and Challenges in Researching IoT Startups .....	61
5.2.	Future Directions and Opportunities .....	63
	<b>Bibliography .....</b>	<b>65</b>
	<b>Table of Figures.....</b>	<b>69</b>

# Introduction

The Internet of Things (IoT) has emerged as one of the most transformative technological paradigms of the 21st century, redefining the way physical devices interact with digital systems. IoT enables the integration of everyday objects with sensors, actuators, and communication networks to create interconnected ecosystems capable of collecting, analyzing, and acting upon data autonomously. This paradigm shift is not merely a technological evolution but a foundational change in how industries operate, how businesses innovate, and how individuals experience technology in their daily lives. From smart homes to industrial automation and healthcare, IoT has become a cornerstone of modern innovation (Srinivasa & Siddaraju, 2019).

The global IoT market is undergoing exponential growth. Its valuation is projected to increase from \$714.48 billion in 2024 to \$4.06 trillion by 2032, reflecting a compound annual growth rate (CAGR) of 24.3% (Precedence Research, 2024). This growth is driven by advancements in complementary technologies such as artificial intelligence (AI), edge computing, blockchain, and cloud computing. The proliferation of IoT-enabled devices has also played a critical role, with over 25 billion devices expected to be connected by 2030 (Statista, 2025). These devices are not only transforming industries but also reshaping consumer behavior and expectations. For instance, IoT has enabled the development of smart cities, where intelligent infrastructure optimizes resource allocation, enhances public safety, and improves the quality of life for residents (Kitchin, 2014).

Startups have emerged as key players in this rapidly evolving ecosystem. Unlike established corporations that often focus on scaling existing solutions, startups are uniquely positioned to explore uncharted territories within IoT innovation. They leverage cutting-edge technologies to address specific challenges such as energy efficiency, real-time monitoring, and predictive maintenance while creating new business models that disrupt traditional industries (Kaspersky, 2025). However, the journey for IoT startups is fraught with challenges. These include scalability issues stemming from the hardware-software convergence required in IoT systems, interoperability hurdles due to fragmented standards, cybersecurity vulnerabilities arising from the expanded attack surface of connected devices, and regulatory compliance complexities that vary across regions and industries (Srinivasa & Siddaraju, 2019).

Moreover, IoT startups must navigate complex ecosystems that involve partnerships with suppliers, manufacturers, and service providers. The ability to manage these relationships effectively is crucial for ensuring timely product development, maintaining quality standards, and achieving market penetration. For example, startups like Samsara have successfully scaled their IoT solutions for industrial fleet management by forging strategic partnerships with major automotive manufacturers and logistics companies (Samsara, 2023).

# 1 The Internet of Things

The Internet of Things is a technological framework that connects physical objects to digital systems through sensors, actuators, and communication networks. This interconnectedness allows devices to collect data from their environment, process it intelligently, and perform actions based on real-time insights. The concept extends beyond mere connectivity; it encompasses the creation of intelligent systems capable of autonomous decision-making and interaction with other devices or users (Srinivasa & Siddaraju, 2019).

IoT represents a convergence of multiple technologies that have evolved over decades. The conceptual origins can be traced back to Mark Weiser's vision of ubiquitous computing in the late 1980s at Xerox PARC. Weiser envisioned a world where technology would become so seamlessly integrated into daily life that it would "disappear" from conscious awareness (Weiser, 1991). This vision laid the foundation for integrating computational capabilities into everyday objects—a principle that became feasible with advancements in sensor miniaturization, wireless communication protocols like Zigbee and LoRaWAN, and low-power embedded systems.

Today's IoT ecosystems are characterized by their ability to enable real-time data collection and analysis across diverse environments such as homes, factories, hospitals, and cities. These ecosystems rely on a combination of hardware components (e.g., sensors), software platforms (e.g., cloud-based analytics), and communication standards (e.g., MQTT) to deliver seamless functionality. For instance, smart home systems integrate sensors for temperature and lighting control with cloud-based AI algorithms to optimize energy consumption and enhance user comfort (Built In, 2025).

## 1.1. Smart Objects

Smart objects form the foundational building blocks of IoT ecosystems. These objects are equipped with sensors for data collection, actuators for executing actions based on processed information or user inputs, and embedded intelligence for local decision-making or data preprocessing before transmission to centralized systems (Srinivasa & Siddaraju, 2019). For example, a smart thermostat monitors room temperature using

sensors while adjusting heating or cooling systems through actuators based on predefined algorithms or user preferences. Wearable health monitors track vital signs such as heart rate or blood pressure continuously while transmitting this data securely to healthcare providers for remote monitoring. Smart speakers integrate voice recognition capabilities with home automation systems enabling users to control lighting appliances through natural language commands. The defining characteristics of smart objects include their ability to sense environmental changes autonomously while communicating securely with cloud platforms via standardized protocols such as MQTT or CoAP. This ensures seamless integration into broader networks and facilitates real-time data exchange between devices and centralized systems (Built In, 2025).

Smart objects also play a critical role in industrial settings. For instance, predictive maintenance in manufacturing relies on sensors embedded in machinery to monitor performance metrics such as vibration and temperature. These sensors transmit data to cloud-based analytics platforms, which use machine learning algorithms to predict potential failures and schedule maintenance accordingly, thereby reducing downtime and enhancing operational efficiency (MDPI Electronics Journal, 2023).

In addition to their functional capabilities, smart objects are designed with user experience in mind. They often incorporate intuitive interfaces that allow users to interact with them easily, whether through voice commands, mobile apps, or physical controls. This user-centric approach is crucial for widespread adoption, as it ensures that smart objects are accessible and beneficial to a broad audience.

Smart objects are increasingly being integrated into smart environments such as smart homes and cities. In these settings, they work in concert with other devices to create holistic ecosystems that optimize energy consumption, enhance safety, and improve quality of life. For example, smart lighting systems in cities can adjust brightness based on ambient light conditions and traffic patterns, reducing energy waste while improving visibility and safety for pedestrians and drivers.

Smart objects also drive innovation in the consumer electronics sector. Wearable devices like smartwatches and fitness trackers have become ubiquitous, providing users with real-time health metrics and personalized recommendations for improving their well-being. These devices often integrate with other smart objects in the home, such as smart speakers or televisions, to create seamless experiences that enhance entertainment and convenience.

Moreover, the development of smart objects is influenced by advancements in materials science and manufacturing technologies. The miniaturization of sensors and

actuators has enabled the integration of smart capabilities into smaller, more discreet devices, expanding their potential applications. For instance, smart contact lenses are being developed to monitor glucose levels for diabetic patients, providing a non-invasive and continuous monitoring solution (Science Daily, 2024).

The economic impact of smart objects is also significant. They have created new business models and revenue streams for companies, particularly in the subscription-based services sector. For example, companies like Nest offer premium services that provide advanced analytics and personalized recommendations for energy efficiency, generating recurring revenue through subscription fees (Nest, 2023).

Smart objects are at the heart of IoT ecosystems, enabling real-time data collection, analysis, and action across diverse environments. Their impact extends beyond technology to influence business strategies, consumer behavior, and societal norms. As IoT continues to evolve, the role of smart objects will only grow more critical, driving innovation and shaping the future of interconnected systems.

## 1.2. Smart Networks

Smart networks form the backbone of IoT systems by enabling seamless communication between devices across various layers of architecture. These networks rely on advanced communication protocols such as LoRaWAN or Zigbee to optimize performance while minimizing energy consumption (MDPI Electronics Journal, 2023). For instance, clustering techniques are often employed within wireless sensor networks to aggregate data locally before transmitting it to centralized servers for analysis. This approach reduces latency while enhancing network efficiency.

Additionally, smart networks incorporate robust security mechanisms such as encryption and authentication protocols to safeguard data integrity against cyber threats (Kaspersky, 2025). As IoT deployments scale globally across industries like healthcare or logistics management systems, the need for increasingly sophisticated network architectures capable of handling diverse operational demands becomes more pressing.

Smart networks also play a crucial role in smart city infrastructure. They enable real-time data collection and analysis, improving everything from traffic management and public safety to energy efficiency and environmental monitoring (Eseye, 2024). For example, smart traffic management systems use IoT sensors to monitor traffic flow and adjust traffic light timing dynamically to reduce congestion and lower emissions.

Smart networks are designed to be scalable and adaptable. They often employ modular architectures that allow for easy integration of new devices or services without disrupting existing operations. This flexibility is essential for IoT systems, which frequently require updates or expansions to accommodate evolving user needs or technological advancements.

In addition to their functional capabilities, smart networks are increasingly incorporating advanced technologies like edge computing and software-defined networking (SDN). Edge computing allows for localized data processing, reducing latency and enhancing real-time decision-making capabilities (101 Blockchains, 2023). SDN, on the other hand, provides a programmable infrastructure that can be centrally managed, enabling more efficient network traffic management and improved adaptability to dynamic conditions (Nature, 2024).

The integration of IoT with SDN has been explored in various applications, including smart libraries. By organizing sensors into subnets and using SDN controllers to manage data exchange, this architecture enhances network efficiency while addressing scalability concerns in large environments (Nature, 2024). This approach demonstrates how smart networks can be optimized for specific use cases, leveraging the strengths of both IoT and SDN technologies.

Moreover, smart networks must address the challenges of interoperability and standardization. IoT devices often operate on different protocols, which can create barriers to seamless communication across heterogeneous networks. Efforts to standardize protocols such as RPL and 6LoWPAN have been instrumental in making IoT systems compatible with conventional infrastructure, facilitating smoother integration into existing networks (MDPI, 2023).

Smart networks are a critical component of IoT ecosystems, enabling efficient data exchange and processing while ensuring security and scalability. As IoT continues to evolve, the sophistication and adaptability of smart networks will remain essential for unlocking the full potential of interconnected systems across diverse industries and applications.

### 1.3. The Internet of Things Architecture

IoT architecture is a multi-layered framework that outlines how various IoT components interact to form a complete IoT system. It typically includes several layers, each with specific roles and components that contribute to the overall functionality of

the IoT system. Understanding these layers is crucial for designing and implementing efficient IoT systems that can collect, process, and act upon data effectively.

The IoT architecture consists of four primary layers: the perception layer, network layer, processing layer, and application layer. Each layer plays a distinct role in ensuring the seamless operation of IoT systems.

The perception layer, also known as the device layer, involves devices, sensors, and actuators that collect and exchange information using protocols like Bluetooth, Wi-Fi, ZigBee, and 6LoWPAN (ResearchGate, 2023). Sensors detect and measure physical properties in the environment, such as temperature, humidity, and motion, providing the essential raw data for IoT analytics (Cavli Wireless, 2024). Actuators perform physical tasks in response to commands from the system, converting data-driven decisions into real-world actions (AIMultiple, 2025).

The network layer ensures smooth data transmission using standards such as 4G, 5G, Wi-Fi, ZigBee, and IPv6. It is responsible for deciding which path data packets should take for sending them back and forth between different networks, utilizing IP addressing to maintain efficiency (Cavli Wireless, 2024). The network layer also includes components like internet gateways and network gateways that facilitate communication between devices and external networks (Device Authority, 2023).

The processing layer manages and processes the data received from the network layer. It includes components such as servers, databases, and cloud platforms, which store and process data for further use. The processing layer performs functions like data aggregation, analysis, and device management, transforming raw data into useful information (Vation Ventures, 2024).

The application layer is where processed data is used to provide useful services to end-users. Applications can range from simple data visualization tools to complex decision-making systems. The application layer delivers actionable insights based on the data collected by IoT devices, serving as the interface between the IoT system and users (Vation Ventures, 2024).

Beyond these primary layers, IoT architecture includes several other components that are essential for its operation. Sensors and actuators are fundamental components of the perception layer, with sensors collecting data on environmental parameters and actuators executing actions based on processed data (AIMultiple, 2025). Internet gateways allow communication outside local systems, enabling data exchange between IoT devices and external networks (Device Authority, 2023). Cloud gateways manage data transmission between IoT devices and cloud platforms, ensuring secure

and efficient data processing (AIMultiple, 2025). Control applications are software components that manage IoT systems, providing interfaces for users to interact with devices and access data insights (AIMultiple, 2025).

The architecture of IoT systems is designed to facilitate efficient data flow from the device level to the application level. It provides a roadmap for integrating components seamlessly, ensuring scalability, compatibility, and security across the entire system (Vation Ventures, 2024). As IoT continues to evolve, the flexibility and adaptability of its architecture will remain crucial for accommodating new technologies and applications.

Moreover, IoT architecture plays a critical role in addressing challenges such as interoperability and security. By standardizing communication protocols and implementing robust security measures, IoT systems can mitigate risks associated with data breaches and ensure reliable operation across diverse environments (Kaspersky, 2025). Interoperability is particularly important as IoT devices often operate on different protocols, which can create barriers to seamless communication across heterogeneous networks. Efforts to standardize protocols such as RPL and 6LoWPAN have been instrumental in making IoT systems compatible with conventional infrastructure, facilitating smoother integration into existing networks (MDPI, 2023).

In addition to addressing interoperability, IoT architecture must also consider scalability. As IoT deployments expand, they involve an increasing number of devices and data streams. The architecture must be able to handle this growth efficiently, ensuring that data processing and transmission remain reliable even under high loads. This is particularly challenging in applications like smart cities, where IoT systems manage vast amounts of data from traffic sensors, environmental monitors, and other sources (Kitchin, 2014).

IoT architecture is evolving to incorporate emerging technologies such as edge computing and artificial intelligence (AI). Edge computing allows for localized data processing, reducing latency and enhancing real-time decision-making capabilities (101 Blockchains, 2023). AI enhances IoT systems by enabling real-time data analysis and decision-making at the edge, improving system responsiveness and efficiency (Built In, 2025).

The integration of IoT with AI and edge computing is transforming various industries. For instance, in manufacturing, predictive maintenance systems use AI to analyze sensor data from machinery, predicting potential failures and scheduling maintenance accordingly. This approach reduces downtime and enhances operational efficiency,

demonstrating the potential of IoT architecture to drive innovation and improve productivity across sectors (MDPI Electronics Journal, 2023).

IoT architecture is a complex yet structured framework that enables the efficient functioning of IoT systems. Its layers and components work together to collect, process, and act upon data, providing valuable insights and services to users. As IoT technology advances, understanding and optimizing its architecture will be essential for unlocking its full potential across various industries and applications. The ongoing evolution of IoT architecture to incorporate new technologies and address emerging challenges will continue to shape the future of interconnected systems.

## 1.4. Technology Clusters

IoT technology clusters represent specialized groups of interconnected devices designed for specific applications such as industrial automation, environmental monitoring, and precision agriculture. These clusters leverage machine learning algorithms to dynamically optimize system performance based on collected datasets. For example, predictive maintenance in manufacturing relies on clustering techniques to identify anomalies in machine behavior before failures occur (MDPI Electronics Journal, 2023).

Technology clusters are instrumental in enhancing the efficiency and effectiveness of IoT deployments. By grouping devices based on their functionality or proximity, clusters can optimize data collection and processing, reducing latency and improving real-time decision-making capabilities. This approach is particularly beneficial in applications where immediate action is required, such as autonomous vehicles or industrial control systems.

Moreover, technology clusters facilitate collaboration between startups and established companies. For instance, the Eclipse ioFog initiative brings together startups and industrial partners to develop open-source edge computing solutions that enhance IoT deployments in real-time applications (Eclipse Foundation, 2024). This collaborative approach reduces R&D costs while ensuring compatibility with enterprise IT infrastructure—a critical factor for startups targeting Fortune 500 clients.

In addition to their operational benefits, technology clusters also drive innovation by fostering ecosystems where diverse stakeholders can share knowledge and resources. This collaborative environment encourages the development of new technologies and business models, which are essential for sustaining growth in the IoT sector. For example, clusters focused on smart cities integrate IoT solutions with urban planning

to optimize resource allocation, enhance public safety, and improve the quality of life for residents (Kitchin, 2014).

Technology clusters also play a significant role in addressing the challenges of IoT scalability and interoperability. By standardizing communication protocols within clusters, IoT systems can ensure seamless interaction between devices from different manufacturers, reducing integration complexities and enhancing overall system reliability (MDPI, 2023). This standardization is particularly important in industrial settings, where the integration of IoT with existing machinery and control systems is critical for achieving operational efficiency.

The economic impact of technology clusters should not be underestimated. They create new business opportunities and revenue streams by enabling companies to offer specialized services tailored to specific industries or applications. For instance, companies specializing in IoT solutions for agriculture can provide precision farming services that enhance crop yields while reducing resource consumption, generating significant economic benefits for farmers and contributing to sustainable agricultural practices (Precision Farming, 2024).

Technology clusters are a vital component of the IoT ecosystem, enabling efficient data processing, enhancing collaboration, and driving innovation across diverse applications. As IoT continues to evolve, the strategic role of these clusters in optimizing system performance, fostering collaboration, and addressing scalability challenges will remain essential for unlocking the full potential of interconnected systems.

## 1.5. The Internet of Things Application Fields

IoT applications span various domains where intelligent systems enhance efficiency and decision-making. These applications are transforming industries and improving quality of life by enabling real-time monitoring, control, and analysis of devices and systems (Neuroject, 2024).

One of the most widely adopted IoT applications is in smart homes, where devices such as thermostats, lighting systems, and security cameras integrate to create automated environments that enhance energy efficiency and user convenience (Built In, 2024). These systems often use natural language processing to interpret voice commands, allowing users to control appliances and lighting through smart speakers (Neuroject, 2024). Additionally, IoT-enabled home security systems provide real-time monitoring and alerts, improving safety and peace of mind for residents (TechTarget, 2023). In assisted living environments, IoT devices can monitor vital signs and detect

falls, enabling timely interventions and improving the quality of life for elderly residents (The Knowledge Academy, 2024). This integration of IoT with healthcare services facilitates remote patient monitoring, allowing healthcare providers to track vital signs continuously and intervene early in case of anomalies (Neuroject, 2024). By automating routine tasks such as medication reminders and scheduling appointments, IoT reduces the burden on caregivers while ensuring consistent care delivery (Fractal, 2019).

Beyond individual homes, IoT plays a crucial role in smart cities, optimizing resource allocation, enhancing public safety, and improving the overall quality of life. IoT sensors monitor traffic flow, air quality, and energy consumption, providing real-time insights that help manage urban infrastructure more efficiently (Kitchin, 2014). For instance, smart traffic management systems dynamically adjust traffic light timing to reduce congestion and lower emissions (Fractal, 2019). Waste management also benefits from IoT, with sensors optimizing collection routes and schedules based on real-time data (Neuroject, 2024). Smart lighting systems adjust brightness based on ambient light conditions and traffic patterns, reducing energy waste while improving visibility and safety for pedestrians and drivers (Built In, 2024). These systems can be integrated with public safety initiatives, such as crime prevention through intelligent surveillance and emergency response systems (TechTarget, 2023). Water supply management further benefits from IoT, with sensors monitoring water quality and detecting leaks, ensuring efficient use of resources and reducing waste (Fractal, 2019).

In healthcare, IoT has revolutionized patient care by enabling remote monitoring, improving diagnostics, and facilitating more personalized treatments (Neuroject, 2024). Wearable devices track vital signs such as heart rate and blood pressure, transmitting data securely to healthcare providers for early intervention (Fractal, 2019). IoT sensors integrated into hospital beds continuously monitor patients' vital signs, enhancing care and reducing the risk of complications (Fractal, 2019). Moreover, smart medical devices controlled remotely improve patient safety and minimize hospital visits (The Knowledge Academy, 2024). Many of these devices leverage AI algorithms to analyze data patterns, predict potential health risks, and provide personalized health recommendations (Neuroject, 2024). The expansion of IoT into telemedicine also enhances healthcare accessibility, particularly for rural or underserved populations, by enabling remote consultations and continuous monitoring (TechTarget, 2023).

Industries also benefit significantly from IoT, particularly in manufacturing and automation, where predictive maintenance, production monitoring, and automation enhance efficiency. Sensors embedded in machinery track performance metrics such as vibration and temperature, predicting failures and scheduling maintenance accordingly (MRCET, 2024). This reduces downtime and maintenance costs while

improving overall productivity (TechTarget, 2023). Additionally, smart supply chain management systems use IoT sensors to track inventory levels and monitor logistics in real-time, optimizing operations and minimizing delays (The Knowledge Academy, 2024). Quality control is another critical application, with IoT monitoring production parameters and detecting anomalies early in the production cycle (Fractal, 2019). The use of IoT-enabled robots in assembly lines further enhances precision and speed, improving product quality while reducing labor costs (Built In, 2024).

In the agricultural sector, IoT has transformed farming practices through precision agriculture, optimizing crop yields while reducing resource consumption. Sensors monitor soil moisture, temperature, and nutrient levels, providing farmers with detailed insights to make informed decisions about irrigation, fertilization, and pest control (Fractal, 2019). Livestock monitoring also benefits from IoT, with sensors tracking animal health and behavior to improve welfare and reduce disease outbreaks (The Knowledge Academy, 2024). Beyond agriculture, environmental monitoring leverages IoT to collect data on air, water, and soil quality, helping organizations predict natural disasters and manage wildlife populations more effectively (TechTarget, 2023). Government agencies and companies use this data to reduce environmental impact and comply with regulations (TechTarget, 2023). Forestry management also integrates IoT, allowing for continuous monitoring of tree health and early detection of diseases or pests, leading to proactive protection of forests (Fractal, 2019).

The transportation sector sees extensive IoT integration, particularly in connected cars and fleet management. Networked vehicles incorporate sensors and communication systems to enhance safety, navigation, and fuel efficiency (Neuroject, 2024). Fleet management systems use IoT sensors to monitor vehicle performance, track routes, and optimize logistics, reducing fuel consumption and emissions while improving delivery times (Fractal, 2019). Urban mobility is also improved through IoT-enabled public transportation systems that optimize routes and schedules, reducing congestion and enhancing the passenger experience (Built In, 2024). Smart parking systems further contribute to efficient urban transport by guiding drivers to available parking spots, reducing traffic congestion and improving accessibility (Fractal, 2019).

In the energy sector, IoT plays a crucial role in optimizing energy distribution and consumption. Smart grids use IoT sensors to monitor energy usage in real-time, enabling utilities to manage supply and demand efficiently (TechTarget, 2023). Smart metering systems provide consumers and businesses with detailed insights into energy consumption patterns, promoting energy efficiency (Built In, 2024). Renewable energy systems also benefit from IoT, with sensors in wind turbines monitoring wind speed and direction, adjusting blade angles to maximize energy production (Fractal,

2019). The integration of IoT with renewable energy sources enhances efficiency and reliability, contributing to a more sustainable energy landscape (Neuroject, 2024).

IoT applications are diverse and transformative, impacting sectors ranging from healthcare and manufacturing to agriculture and transportation. As IoT technology continues to evolve, its applications will play an increasingly critical role in enhancing efficiency, improving decision-making, and shaping the future of interconnected systems. The ongoing expansion of IoT into new domains will continue to drive innovation and improve quality of life, underscoring its importance as a foundational technology for the digital age.

## 1.6. The Market Landscape

The IoT market landscape, up to 2024, is characterized by rapid expansion driven by technological advancements and increasing adoption across sectors like healthcare, automotive manufacturing, retail logistics management among others. Emerging markets, particularly in the Asia-Pacific region, show higher adoption rates due to government initiatives and consumer demand for smart technologies (Statista, 2024).

The global IoT market is projected to reach \$1.387 billion by 2024, growing at an annual rate of 12.5% (Precedence Research, 2024). This growth is fueled by advancements in complementary technologies such as artificial intelligence (AI), edge computing, blockchain, and cloud computing. The proliferation of IoT-enabled devices has also played a critical role, with over 20 billion devices expected to be connected by 2024 (Statista, 2024). These devices are not only transforming industries but also reshaping consumer behavior and expectations.

Moreover, the IoT market is witnessing a surge in strategic partnerships between startups and established companies. These partnerships facilitate access to advanced technologies, enhance scalability, and provide startups with the resources needed to navigate complex regulatory environments. For instance, collaborations between IoT startups and automotive giants have led to the development of smart vehicle systems that integrate real-time traffic data with navigation systems to optimize route planning and reduce fuel consumption (Samsara, 2023).

The market is also influenced by trends such as the integration of AI and edge computing. AI enhances IoT systems by enabling real-time data analysis and decision-making at the edge, reducing latency and improving system responsiveness (101 Blockchains, 2023). Edge computing, in turn, allows for localized data processing,

which is critical for applications requiring immediate action, such as autonomous vehicles or industrial control systems (Kitchin, 2014).

Furthermore, the IoT market is characterized by a significant presence of startups that are driving innovation within this domain. These startups leverage cutting-edge technologies to address specific challenges such as energy efficiency, real-time monitoring, and predictive maintenance while creating new business models that disrupt traditional industries (Kaspersky, 2024). However, these startups face significant hurdles, including scalability issues stemming from the hardware-software convergence required in IoT systems, interoperability hurdles due to fragmented standards, cybersecurity vulnerabilities arising from the expanded attack surface of connected devices, and regulatory compliance complexities that vary across regions and industries (Srinivasa & Siddaraju, 2019).

In addition to these challenges, IoT startups must navigate complex ecosystems that involve partnerships with suppliers, manufacturers, and service providers. The ability to manage these relationships effectively is crucial for ensuring timely product development, maintaining quality standards, and achieving market penetration. For example, startups like Samsara have successfully scaled their IoT solutions for industrial fleet management by forging strategic partnerships with major automotive manufacturers and logistics companies (Samsara, 2023).

Moreover, the IoT market is influenced by government policies and regulations. Governments worldwide are implementing initiatives to encourage IoT adoption while ensuring data privacy and security. For instance, the European Union's General Data Protection Regulation (GDPR) sets stringent standards for data protection, which IoT companies must comply with to operate in the region (European Union, 2023). Similarly, in the United States, the Federal Trade Commission (FTC) has guidelines for IoT security and privacy, emphasizing the importance of secure-by-design principles in IoT product development (FTC, 2023).

The economic impact of IoT is also significant. IoT has created new business models and revenue streams for companies, particularly in the subscription-based services sector. For example, companies like Nest offer premium services that provide advanced analytics and personalized recommendations for energy efficiency, generating recurring revenue through subscription fees (Nest, 2023). This shift towards service-oriented models is transforming traditional industries by creating opportunities for companies to offer value-added services that enhance customer experiences and improve operational efficiency.

IoT market landscape up to 2024 is dynamic and rapidly evolving, driven by technological advancements, strategic partnerships, and emerging trends such as AI and edge computing. As IoT continues to expand across industries, addressing challenges like interoperability, security, and regulatory compliance will remain essential for sustaining growth and unlocking the full potential of interconnected systems. The ongoing innovation in IoT will continue to shape industries and transform how businesses operate, making it a critical component of the digital transformation underway globally.

### **Extended Analysis of IoT Market Trends**

The IoT market is also witnessing a rise in the adoption of IoT in consumer electronics. Smart home devices such as smart speakers and smart TVs are becoming increasingly popular, with companies like Amazon and Google leading the market with their Alexa and Google Assistant platforms (Built In, 2024). These devices integrate AI capabilities to enhance user experience, providing voice-controlled interfaces for managing home appliances and accessing information.

Moreover, the IoT market is influenced by the emergence of new business models. Companies are shifting from traditional product sales to service-based offerings, where IoT devices are integrated with cloud services to provide ongoing support and updates. This model enhances customer engagement while generating recurring revenue streams for companies (Nest, 2023).

In addition, IoT is transforming the retail sector by enabling smart inventory management and personalized customer experiences. IoT sensors track inventory levels in real-time, optimizing stock replenishment and reducing waste. Retailers also use IoT to enhance customer engagement through personalized marketing and loyalty programs, improving customer retention and driving sales (Fractal, 2019).

The integration of IoT with other technologies such as blockchain is also gaining traction. Blockchain enhances IoT security by providing a secure and transparent way to manage data exchange between devices, reducing the risk of data breaches and ensuring trust in IoT systems (Kaspersky, 2024).

The IoT market landscape up to 2024 is characterized by rapid growth, strategic partnerships, and innovative applications across industries. As IoT continues to evolve, its impact on business models, consumer behavior, and technological innovation will remain significant, shaping the future of interconnected systems and driving digital transformation globally.

## 1.7. The Internet of Things Startups

IoT startups have emerged as pivotal players in driving innovation within the IoT ecosystem. These startups leverage cutting-edge technologies to develop novel solutions that address pressing challenges while opening up new market opportunities. However, their journey is not without challenges, as they must navigate issues such as scalability, interoperability, security vulnerabilities, and regulatory compliance.

Emerging trends in IoT startups include the integration of artificial intelligence (AI) into IoT systems to enhance data analysis and decision-making capabilities. AI enables IoT devices to learn from data patterns, predict anomalies, and optimize performance autonomously (Built In, 2024). The shift towards edge computing is also gaining momentum as startups recognize its potential to reduce latency and enhance real-time processing capabilities. Edge computing allows IoT systems to process data closer to the source, which is critical for applications requiring immediate action (101 Blockchains, 2023).

Security and compliance have become critical concerns as IoT deployments expand. Startups are focusing on developing secure-by-design solutions that meet stringent regulatory standards, such as GDPR and HIPAA, to safeguard user data and maintain trust in IoT systems (Kaspersky, 2024).

In 2024, several IoT startups have gained prominence for their innovative solutions. Artisight is known for its advanced IoT solutions that integrate hardware and software to provide spatial insights and device management capabilities (CRN, 2024). Memfault offers a cloud-based platform for monitoring, debugging, and updating IoT devices, enhancing device reliability and efficiency (CRN, 2024). Morse Micro develops long-range, low-power Wi-Fi HaLow connectivity chip solutions to improve IoT device connectivity (CRN, 2024). Nozomi Networks focuses on protecting critical infrastructure with a platform that combines network and endpoint visibility, threat detection, and AI-powered analysis (CRN, 2024).

Moreover, startups like Nanit are making significant strides in consumer IoT, offering smart baby monitoring systems that use computer vision and machine learning to track sleep patterns and provide personalized insights (Exploding Topics, 2024). Wiliot, another notable startup, connects products to the internet using its patented IoT Pixel technology, providing valuable insights into product usage and lifecycle management (Exploding Topics, 2024).

The IoT startup landscape in 2024 is characterized by rapid growth and diversification. According to IoT Analytics, there are over 3,300 active IoT startups, marking a significant increase from the 1,205 identified in 2021 (IoT Analytics, 2024). This growth reflects the increasing interest in IoT across various sectors, particularly in Asia-Pacific, where the number of startups has risen substantially (Next4, 2024).

The focus of IoT startups is shifting towards smart cities and energy/utilities, with AI and data analytics becoming increasingly prominent offerings (IoT Analytics, 2024). Techstars remains a leading investor in IoT startups, highlighting the importance of venture capital in supporting innovation in this space (IoT Analytics, 2024).

IoT startups often rely on strategic partnerships to access advanced technologies and scale their operations. For instance, collaborations between IoT startups and major automotive companies have led to the development of smart vehicle systems that integrate real-time traffic data with navigation systems to optimize route planning and reduce fuel consumption (Samsara, 2023).

Funding is also crucial for IoT startups. Many have secured significant investments in recent years. For example, Memfault raised a \$24 million Series B funding round in 2023, which was led by Stripes and other investors (CRN, 2024). This funding supports the development of innovative IoT solutions and helps startups navigate complex regulatory environments.

Despite their potential, IoT startups face several challenges. Scalability issues arise from the need to integrate hardware and software components seamlessly, while ensuring compatibility across diverse systems (Srinivasa & Siddaraju, 2019). Interoperability remains a significant hurdle due to fragmented standards, which can hinder seamless communication between devices from different manufacturers (MDPI, 2023).

Cybersecurity vulnerabilities are also a major concern, as IoT devices expand the attack surface for potential cyber threats (Kaspersky, 2024). Regulatory compliance adds another layer of complexity, with startups needing to adhere to varying standards across regions and industries (European Union, 2023).

As IoT continues to evolve, startups will remain at the forefront of innovation. The integration of emerging technologies like AI and edge computing will continue to enhance IoT systems, enabling real-time data analysis and decision-making at the edge (101 Blockchains, 2023). This trend will drive further growth in IoT adoption across industries, creating new opportunities for startups to develop disruptive solutions.

Moreover, IoT startups are expected to play a pivotal role in shaping the future of smart cities. By developing innovative solutions for urban infrastructure management, energy efficiency, and public safety, these startups will contribute to improving the quality of life for urban residents while enhancing sustainability and efficiency in urban environments (Kitchin, 2014).

IoT startups are making significant impacts in various sectors. In healthcare, startups like Nanit are leveraging IoT to enhance patient care through remote monitoring and personalized health insights. This approach is improving health outcomes while reducing healthcare costs associated with prolonged hospital stays (Exploding Topics, 2024).

In industrial automation, companies like Samsara are transforming industrial operations by integrating IoT with predictive maintenance and real-time monitoring, enhancing operational efficiency and reducing downtime (Samsara, 2023).

In smart cities, IoT startups are developing innovative solutions for urban management, including smart traffic systems and energy-efficient infrastructure, which are improving public services and enhancing sustainability in urban environments (Kitchin, 2014).

IoT startups are not only driving technological innovation but also transforming business models and consumer behavior. By offering subscription-based services and data-driven insights, these startups are creating new revenue streams and enhancing customer engagement. For example, companies like Nest offer premium services that provide advanced analytics and personalized recommendations for energy efficiency, generating recurring revenue through subscription fees (Nest, 2023).

Moreover, IoT startups are influencing consumer behavior by providing personalized experiences and real-time feedback. This shift towards more interactive and responsive products is changing how consumers interact with technology, fostering a more connected and automated lifestyle (Built In, 2024).

IoT startups are driving innovation and growth in the IoT ecosystem. Their ability to leverage cutting-edge technologies and address specific challenges will remain crucial for unlocking the full potential of interconnected systems. As the IoT landscape continues to evolve, startups will play a pivotal role in shaping the future of industries and transforming how businesses operate. The ongoing innovation in IoT will continue to drive digital transformation globally, underscoring the importance of IoT as a foundational technology for the digital age.

## 1.8. Emerging Trends

Emerging trends in IoT startups are transforming the landscape of innovation and growth within the IoT ecosystem. These trends not only reflect technological advancements but also highlight the evolving needs of industries and consumers. The integration of AI and ML with IoT solutions is leading to smarter devices and more efficient processes. IoT devices collect vast amounts of data, but with AI and ML, this data can be analyzed and utilized in real-time. This enables predictive maintenance, improves customer service, and optimizes business processes. An example is in logistics, where smart sensors and AI algorithms help optimize routes, predict delays, and enhance supply chain efficiency. Organizations investing in advanced connectivity platforms can respond more quickly to changes and strengthen their competitive position.

Moreover, AI is expected to transform IoT devices into truly intuitive systems capable of anticipating and adapting to user needs. At the 2025 Consumer Electronics Show (CES), significant progress was made in this direction, with companies like Synaptics unveiling scalable embedded computing solutions designed for multimodal Edge AI workloads. These platforms simplify Edge AI application development across consumer, enterprise, and industrial markets by combining purpose-built hardware with open-source software, focusing on privacy-conscious solutions that process sensitive data locally, boosting security, reducing latency, and enabling real-time decision-making.

Sustainability remains a central theme worldwide, with IoT playing a crucial role in smart energy management. IoT-powered systems help organizations monitor and optimize their energy consumption. Sensors in buildings detect when spaces are not in use and automatically turn off lighting or climate control. Additionally, Low Power Wide Area Networks (LPWAN) like LTE-M and NB-IoT provide energy-efficient connections. Solutions like those offered by Thingsdata help organizations reduce energy consumption through real-time monitoring and automatic adjustments, saving costs and reducing their environmental footprint.

In 2025, IoT sensors and smart cameras are set to work together more closely than ever, reshaping how we think about safety and efficiency in smart cities. Cameras powered by AI analyze situations in real-time, detecting issues like traffic jams or suspicious activities and triggering automated responses and alerts. For instance, they could streamline traffic management or enhance public safety by immediately notifying authorities of potential incidents. IoT sensors are also advancing with onboard image processing capabilities. This allows them to capture and process visual data, sending

only precise and streamlined information over low-power networks. This reduces network congestion while improving the speed and accuracy of communication. Together, these technologies promise smarter, more responsive smart cities where systems operate in unison to enhance situational awareness and overall functionality.

In 2025, organizations implementing smart solutions will face a more streamlined approach to connectivity. The wide variety of network technologies and devices that have cluttered the market will start to consolidate, making it easier to adopt and scale IoT systems. Fragmentation in network options has been a challenge for businesses, but recent developments signal a shift towards more unified solutions. However, NB-IoT will continue to play a crucial role in certain regions, such as the UK, where it may work alongside other networks. Additionally, LoRaWAN technology will remain a flexible and cost-effective option for smart city projects and smart buildings, where local control and service delivery are critical. In 2025, there will be an acceleration of collaboration among managed LoRaWAN service providers, bringing about better integration and network sharing. Hybrid connectivity models will also gain traction, combining the strengths of different network types, like cellular and LoRaWAN, to deliver reliable and consistent performance, reducing risks and enabling broader adoption of smart solutions.

The IoT market is witnessing a significant shift from sensor-based data to video-based data. This trend is driven by the increasing integration of IoT with video analytics, which provides more comprehensive insights into operational environments. Video-based data can offer detailed visual information, enhancing monitoring and decision-making capabilities across industries such as security and surveillance. Moreover, AI will play a crucial role in processing video data, enabling real-time analysis and decision-making. This integration of AI with video analytics is expected to transform industries like manufacturing and logistics by providing visual insights that can predict potential issues and optimize processes.

IoT is driving modernization in manufacturing by enabling Industry 4.0 technologies. This involves integrating IoT with AI, robotics, and data analytics to create smart factories that are more efficient and responsive to market demands. Modernized manufacturing will shape the future of industry by enhancing productivity, reducing costs, and improving product quality. The combination of IoT, AI, and 5G technology will propel beyond visual line of sight (BVLOS) drone operations to the forefront of commercial applications by 2025. IoT sensors embedded in drones provide real-time situational awareness, allowing for autonomous flight over extended distances and in challenging environments like densely populated areas or remote locations. These

advancements will unlock use cases such as last-mile delivery, large-scale agricultural monitoring, and precision inspections for industrial sites.

Edge computing is becoming increasingly important in IoT, as it allows for real-time data processing closer to the source. This reduces latency and enhances system responsiveness, which is critical for applications requiring immediate action, such as autonomous vehicles or industrial control systems. Moreover, edge computing enables IoT devices to make autonomous decisions without relying on centralized cloud infrastructure, improving efficiency and reducing bandwidth usage. This trend is driving innovation in IoT applications across industries, from smart homes to industrial automation, by providing faster and more reliable data processing capabilities.

In 2025, there is an emerging trend towards emotion-aware devices that can sense and respond to human emotions. This human-centric approach to IoT aims to create more personalized and empathetic interactions between humans and devices, enhancing user experience and satisfaction. Moreover, emotion-aware devices are expected to play a significant role in healthcare and wellness applications, where they can monitor emotional states and provide personalized interventions to improve mental health outcomes.

There is also a growing need for IoT solutions that can operate effectively in 'less connected' environments. This trend reflects the importance of IoT in remote or underserved areas where connectivity may be limited. IoT devices designed for these environments must be able to function autonomously or with minimal connectivity, using edge computing and local data processing to maintain functionality. In conclusion, emerging trends in IoT startups are driving innovation and growth across various sectors. From AI integration to network consolidation and beyond, these trends highlight the evolving nature of IoT and its potential to transform industries and improve quality of life. As IoT continues to evolve, startups will remain at the forefront of innovation, leveraging these trends to develop disruptive solutions that address specific challenges and create new opportunities for growth and efficiency.



## 2 Objectives and methodologies

### 2.1. Objectives

Question 1: What is the current state of startups operating in the IoT sector?

The primary objective of this study is to comprehensively examine the current state of startups within the global Internet of Things (IoT) ecosystem. This research aims to provide a detailed overview of the industry's landscape in recent years, highlighting the various factors that have influenced its development. Specifically, the thesis seeks to identify the geographical regions where IoT startups are most densely concentrated and provide insights into the factors that contribute to these clusters.

Moreover, this research will analyze the financial aspects of IoT startups, investigating the total amount of funding raised, the sources of funding, and how it is distributed across different regions. Another key aspect of this study will be to understand the stages of development where most IoT startups currently stand—whether they are in early stages (such as seed funding) or in more advanced phases like growth or expansion.

Furthermore, the study will explore the core functionalities and innovations that these startups are focusing on, identifying the key challenges they aim to address within the IoT sector. The trends that attract the most interest from investors will be examined, providing insight into the areas within IoT that have the highest potential for growth and return on investment. Lastly, the research will categorize the types of products and services offered by these startups, offering a comprehensive view of the market and its trajectory.

Given the rapid expansion of IoT technologies across multiple industries, this study will assess the role of IoT startups in shaping digital transformation and industrial innovation. With IoT influencing fields such as healthcare, smart cities, agriculture, and industrial automation, this research will also highlight cross-industry applications and synergies that drive IoT growth. The analysis will aim to uncover whether startups are predominantly innovating in niche areas or attempting to establish comprehensive IoT platforms capable of integrating multiple services and devices.

## Question 2: What business models are IoT startups favoring?

As discussed earlier, startups are at the forefront of IoT innovation, creating new technologies and business models that transform industries. A startup's ability to innovate is essential not only for survival but for achieving differentiation in a highly competitive market. This research will assess which business models are most commonly adopted by IoT startups and how they align with industry demands.

A crucial aspect of this study is also the evaluation of monetization strategies adopted by IoT startups. The business models of IoT companies range from hardware sales and software-as-a-service (SaaS) to data monetization and subscription-based services. Understanding these models is essential for determining how startups sustain their operations and attract investment.

By analyzing these factors, this study will provide insights into whether IoT startups are prioritizing scalability, recurring revenue streams, or other growth-oriented strategies. The results will help identify which business models are most successful and sustainable in the rapidly evolving IoT sector.

This study will also explore the extent to which IoT startups rely on platform-based business models versus direct product sales. Platform business models, where startups provide connectivity and analytics services rather than just standalone hardware or software, have become increasingly prominent. By evaluating case studies of successful IoT startups, this thesis will assess whether platform-centric models are more viable in the long term compared to traditional hardware-based approaches.

## 2.2. Methodological Approach: Literature Review and Interviews

This thesis consists of two main parts: a literature review that provides a foundational understanding of IoT startups and their business models, and an empirical analysis based on a database of startups, created using structured data collection methods.

### 2.2.1. Literature Review

The literature review was essential for building the theoretical foundation of this research. It involved analyzing academic papers, industry reports, and market research studies to understand IoT startup trends, business models, and technological advancements.

Key sources included:

- **Academic databases** (Scopus, Google Scholar, IEEE Xplore, ResearchGate, ScienceDirect)
- **Industry reports** (McKinsey, Gartner, CB Insights, PitchBook, IDC, Deloitte, PwC, World Economic Forum, Harvard Business Review, European Commission, Straits Research, ABI Research, Statista, Precedence Research, MIT Technology Review, Nature, Built In, AIMultiple, 101 Blockchains, Neuroject, TechTarget, CRN, Device Authority, Vation Ventures, Samsung, Gartner, Kaspersky, Samsara, Nest, MDPI Electronics Journal, Harvard Business School, Eclipse Foundation, Exploding Topics, Precision Farming, Fractal, The Knowledge Academy, Eseye, Samsung, Cavli Wireless)
- **Publications from venture capital firms and IoT-focused incubators** to assess investment trends and market dynamics. (PitchBook, CB Insights, Techstars, Next4, IoT Analytics)
- **The IoT startup database was built using Crunchbase and other publicly available sources.**

### 2.2.2. Census

Following the literature review, a structured census of IoT startups was conducted to compile a comprehensive dataset. The main data source was Crunchbase, a global business information platform that tracks startups from early-stage funding to large-scale operations.

The selection criteria included:

1. Active startups (excluding those that have shut down);
2. Companies founded after 2020;
3. Startups operating in IoT-related sectors, such as "Connected Devices," "Smart Cities," "Industrial IoT," "Wearables," and similar fields.

A query was constructed in Crunchbase's advanced search function using the following filters:

- **Closed Date:** Blank, ensuring only active businesses were included.
- **Acquired Date:** Blank, excluding non-operating companies.
- **Last Funding Date:** After January 1, 2020, to focus on recently active startups.
- **Industries:** "IoT," "Connected Devices," "Smart Cities," "Industrial IoT," "Wearables," etc.
- **Keywords in descriptions:** "IoT," "Smart Devices," "Connected Tech," etc.

From an initial dataset of over 1,929 companies, a refined list of 432 startups was selected for in-depth analysis.

## 3 Database

This chapter presents an in-depth analysis of the dataset used in this study, which consists of structured information on Internet of Things (IoT) startups. The dataset compiles key business characteristics, technological clusters, geographic distribution, funding details, and acquisition status of various IoT startups. This dataset serves as the foundation for analyzing industry trends, regional patterns, funding dynamics, and acquisition tendencies within the IoT ecosystem.

The dataset categorizes IoT startups based on technology clusters, IoT application areas, business orientation (B2B, B2C, B2D), offering type (hardware, software, service), geographical presence, revenue range, employee size, and assigned business model. By systematically analyzing these attributes, the dataset provides valuable insights into the diverse landscape of IoT startups and how they position themselves in the market. The categorization also helps in identifying emerging trends, key industry players, and the evolution of business strategies in the IoT ecosystem. As the industry continues to expand, understanding these classifications becomes crucial for stakeholders looking to invest, partner, or compete within the space.

The database includes company information such as name, website, description, and founding year, offering a foundational understanding of each startup's identity and core operations. It also details the technological and business focus of these companies, highlighting the specific IoT solutions they develop and their targeted applications. Additionally, the geographical presence of each startup is recorded, allowing for a regional analysis of IoT growth hotspots and innovation hubs. Financial data, including funding details and revenue figures, provide insight into the economic viability and investment appeal of these businesses. Growth indicators, such as employee range and investor types, further contextualize the startup's scalability and market traction. By integrating all these components, the dataset serves as a powerful tool for analyzing the broader IoT startup ecosystem and its potential trajectories.

### Business Model Assignment

Each startup has been mapped to one of the following business models based on its characteristics:

#### 1. MOP Model

- Applied to startups focused on infrastructure, networks, and regulatory-driven industries.

#### 2. DNA Model

- Assigned to startups operating in logistics and supply chain optimization.

#### 3. Value Net Model

- Applied to B2B startups emphasizing collaboration and data integration.

#### 4. Business Model Canvas

- Given to startups with complex ecosystems incorporating hardware, software, and services.

#### 5. 2x2 Matrix Model

- Used for consumer-oriented startups in B2C markets.

#### 6. Three-Dimensional Model

- Assigned to startups combining hardware, software, and services in a layered ecosystem.

The IoT startup database was built using Crunchbase and other publicly available sources. Data extraction followed a structured approach to ensure accuracy and relevance. The final dataset consists of **432 IoT startups** that fit the selection criteria outlined in the previous chapter.

## 3.1. Key Insights from Data Analysis

### 3.1.1. Industry Trends: IoT Application Areas and Technology Clusters

The dataset provides information on the technological and business focus of IoT startups, categorizing them based on their application areas and technological clusters. The most common IoT application areas identified are:

- **Smart Logistics:** Startups focusing on optimizing supply chains and transportation.
- **Smart Grid:** Companies working on energy efficiency, grid monitoring, and distribution.
- **Infrastructure & Networks:** Businesses enhancing connectivity and telecommunication systems.
- Additionally, the most prevalent technological clusters in the dataset include:
- **Wi-Fi and Bluetooth Low-Energy:** Indicating a focus on wireless connectivity solutions.
- **Cellular Networks:** Suggesting applications in mobile and IoT communications.

These findings imply that the majority of IoT startups are engaged in **networking and infrastructure development**, which aligns with the industry's push for improved connectivity and automation. The dominance of connectivity-driven solutions highlights the growing importance of seamless, real-time data exchange, particularly in sectors such as logistics, healthcare, and industrial automation. As businesses and consumers increasingly rely on interconnected devices, the demand for innovative IoT solutions will continue to grow, driving further advancements in networking technologies.

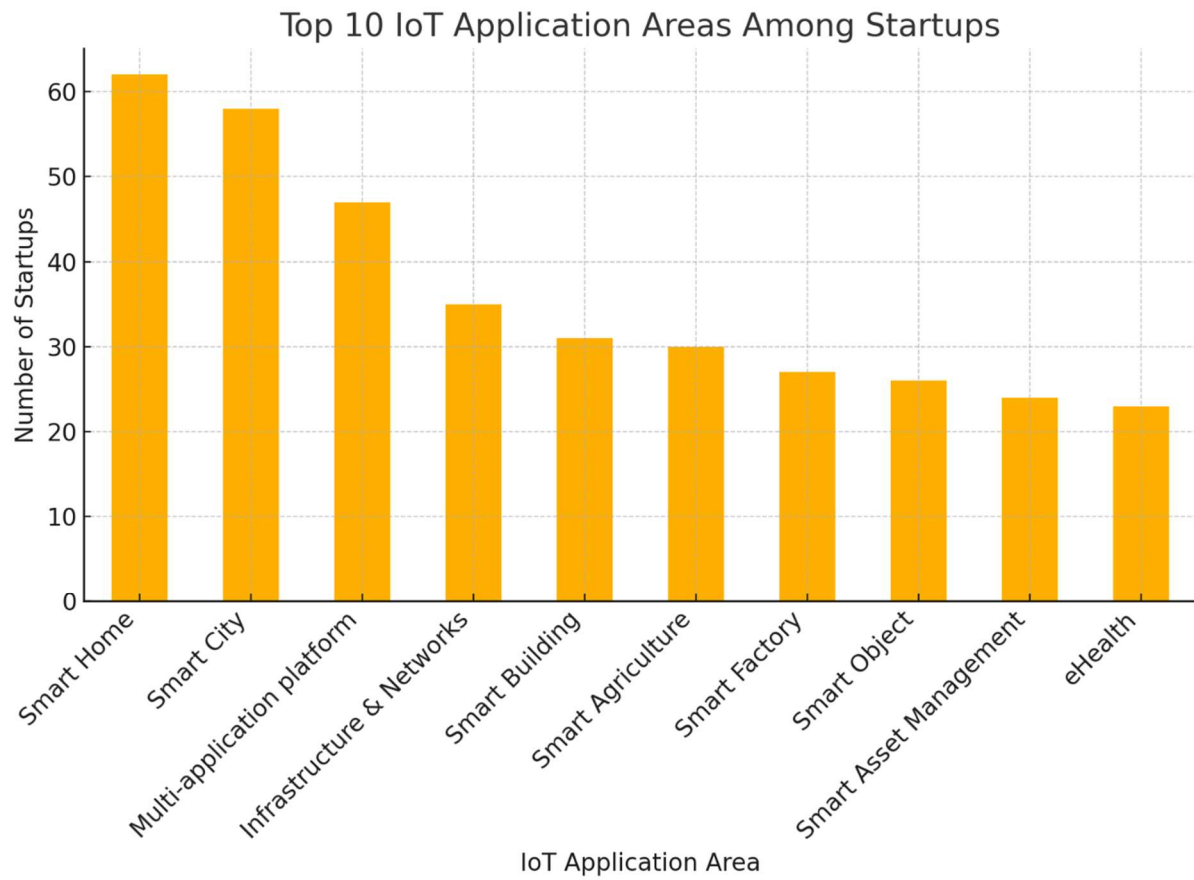


Figure 1: Top 10 IoT Application Area Among Startups (Last 5 years, sample size 465)

### 3.1.2. Yearly Distribution of IoT Startup Foundations

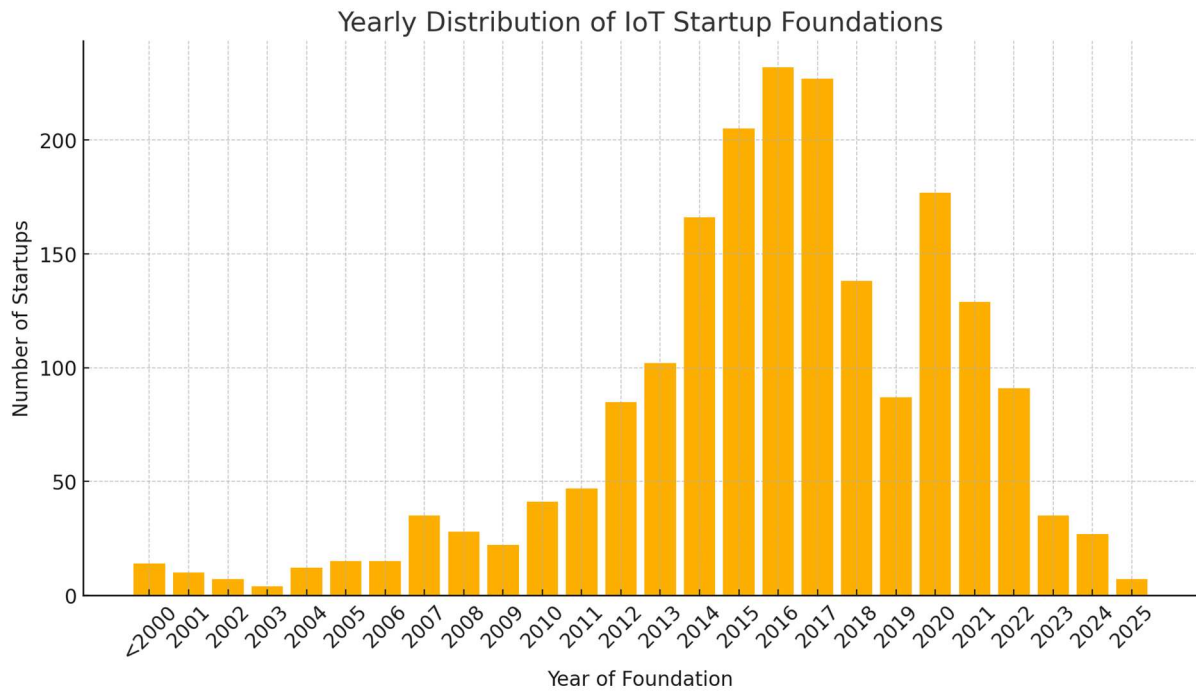


Figure 2:Yearly Distribution of IoT Startup Foundation (Sample size 1960)

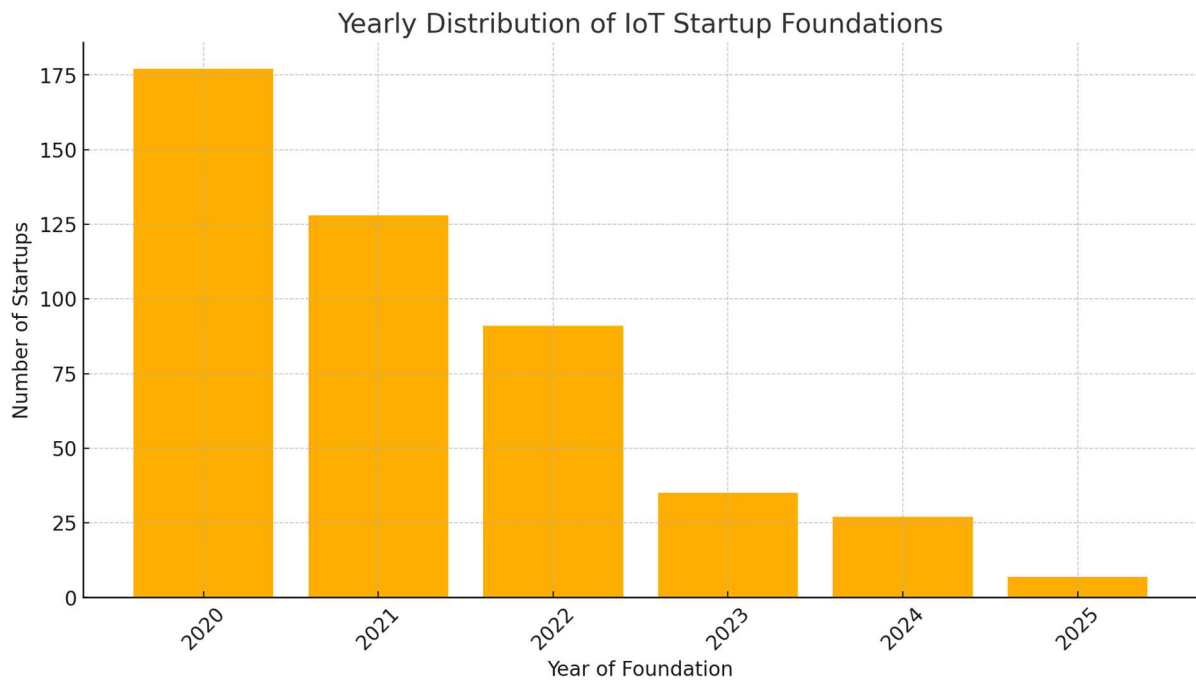


Figure 3:Yearly Distribution of IoT Startup Foundation (Last 5 years, sample size 465)

The analysis of the yearly distribution of IoT startup formations based on the dataset reveals significant shifts in the industry. The number of startups founded each year has fluctuated dramatically, with a notable peak in 2020, when 177 IoT startups were established, followed by a steep decline, reaching its lowest point in 2023 with only 35 new startups (Startup Database, 2024). This represents an 80% drop in startup formation over just three years, highlighting a major shift in the IoT landscape.

Expanding the analysis to include the broader dataset, IoT startup formation has been recorded as early as 1958, though significant growth only began in the 2000s. The most active period for startup formation was in 2016, which saw the highest number of new companies established, reaching 232 startups. Prior to 2000, only 10 startups were recorded, indicating that IoT entrepreneurship is largely a product of recent technological advancements. However, there have been multiple periods of decline, including drops in 2002, 2003, 2008, 2009, and a noticeable downturn after 2017. These fluctuations suggest that IoT startup formation has been influenced by broader economic cycles, regulatory changes, and technological breakthroughs.

The early 2000s saw limited IoT startup formation, likely due to the dot-com bubble burst, which led to reduced investment in emerging tech ventures and made it harder for startups to secure funding (Harvard Business Review, 2002). The financial crisis of 2008 had a similar impact, causing economic uncertainty that reduced risk-taking by investors and limited capital availability for IoT-focused companies (World Bank, 2009). Conversely, the rapid rise in startup formation after 2010 can be linked to advancements in wireless connectivity, cloud computing, and the proliferation of smart devices, which created a fertile environment for new IoT solutions (MIT Technology Review, 2011). The introduction of widespread 4G networks, for example, made it significantly easier to deploy connected devices, further accelerating IoT startup growth (Gartner, 2012).

The surge in 2020 can be attributed to several key factors. The COVID-19 pandemic accelerated digital transformation across industries, driving demand for automation, remote monitoring, and smart logistics solutions (World Economic Forum, 2021). Businesses sought to enhance operational efficiency, reduce reliance on human labor, and improve supply chain resilience, all of which fueled increased investment in IoT startups (McKinsey & Company, 2022). Additionally, technological advancements such as 5G, AI-driven analytics, and edge computing created new opportunities for innovation, making it easier for startups to develop scalable IoT solutions (Gartner, 2021). With heightened investor confidence and widespread adoption of connected technologies, 2020 became the peak year for IoT startup formation. Furthermore, government initiatives in various countries promoting smart infrastructure and digital transformation further bolstered startup activity, particularly in sectors such as healthcare, manufacturing, and urban mobility (OECD, 2021).

However, following this peak, the industry saw a steady decline in new startups, culminating in a sharp drop by 2023. This downturn suggests a transition from rapid expansion to market consolidation (CB Insights, 2023). One of the primary reasons for this shift is the slowdown in venture capital funding, with investors becoming more selective and favoring established IoT companies over new entrants (PitchBook, 2023). Economic uncertainty, rising inflation, and supply chain disruptions have also played a role in discouraging new business formation, as market conditions have become less favorable for high-risk, capital-intensive ventures (Harvard Business Review, 2023). Additionally, regulatory challenges related to data privacy, cybersecurity, and network interoperability have made it more difficult for new startups to enter the IoT space (European Commission, 2023). These increasing compliance requirements may have raised barriers to entry, forcing smaller players to either pivot or exit the market altogether. Another contributing factor is the saturation of certain IoT markets, where companies that emerged in the early 2010s have matured, making it harder for new entrants to differentiate themselves and secure market share (BCG, 2023).

Another critical factor behind the decline in startup formation is the growing dominance of large technology firms in the IoT ecosystem. Many major corporations have expanded their IoT capabilities through acquisitions, reducing the need for new startups to develop niche solutions (IDC, 2023). Established companies are increasingly integrating IoT technology into their existing business models, making it harder for new entrants to compete (Deloitte, 2023). As a result, while IoT adoption continues to grow, the industry is witnessing a shift from a highly fragmented startup-driven landscape to one that is more concentrated around a few dominant players. Additionally, large-scale IoT deployments now require significant infrastructure investments, making them less accessible to early-stage startups that lack the necessary capital and partnerships (World Economic Forum, 2023).

Despite this decline, the IoT industry is not slowing down; rather, it is evolving. The future of IoT startups may not be driven by sheer numbers but by the specialization and sophistication of emerging solutions (Forbes, 2024). Instead of a flood of new hardware-focused startups, the next wave of innovation is likely to be centered around software-driven IoT applications, AI-powered analytics, and cybersecurity solutions (MIT Technology Review, 2024). The rise of smart cities, industrial automation, and decentralized IoT networks could define the next phase of growth, potentially leading to the emergence of fewer but more impactful startups (PwC, 2024). Additionally, as IoT adoption expands beyond North America and Europe, emerging markets in South America, Africa, and Southeast Asia may drive the next cycle of startup growth, as businesses in these regions seek cost-effective automation and digital transformation solutions (World Bank, 2024). Furthermore, the growing emphasis on sustainability

and energy-efficient IoT solutions may create opportunities for startups focusing on green technology and resource optimization (IEA, 2024).

The data suggests that the IoT startup ecosystem is entering a new phase, where scaling and market consolidation take precedence over rapid expansion. The peak in 2020 marked an era of accelerated growth, but the sharp decline by 2023 highlights the challenges facing new entrants (Statista, 2024). Moving forward, the industry will likely see a more selective, innovation-driven landscape where fewer but highly specialized startups bring cutting-edge solutions to market. This transition underscores the need for continued research into the evolving dynamics of IoT entrepreneurship and the long-term impact of technological advancements, regulatory policies, and market forces on startup formation trends (Harvard Business School, 2024). Additionally, as enterprises increasingly demand integrated IoT ecosystems rather than isolated solutions, startups that can offer seamless interoperability and robust security features may be better positioned for success in the coming years (McKinsey & Company, 2024).

### 3.1.3. Business Model Segmentation in IoT Startups

IoT startups can be categorized into several **application areas** based on their business models:

1. **B2B (Business-to-Business)** – Dominates the IoT startup landscape, with most companies offering a mix of **hardware, software, and services**.
2. **B2B/B2C Hybrid Models** – Show a strong presence, with a slightly higher share of **software and service-based offerings**.
3. **B2C (Business-to-Consumer)** – Less common, with a focus on **software and services rather than hardware**.
4. **B2D (Business-to-Developer)** – Rare in the dataset, suggesting that IoT companies primarily focus on selling to **businesses or end consumers** rather than targeting developers.

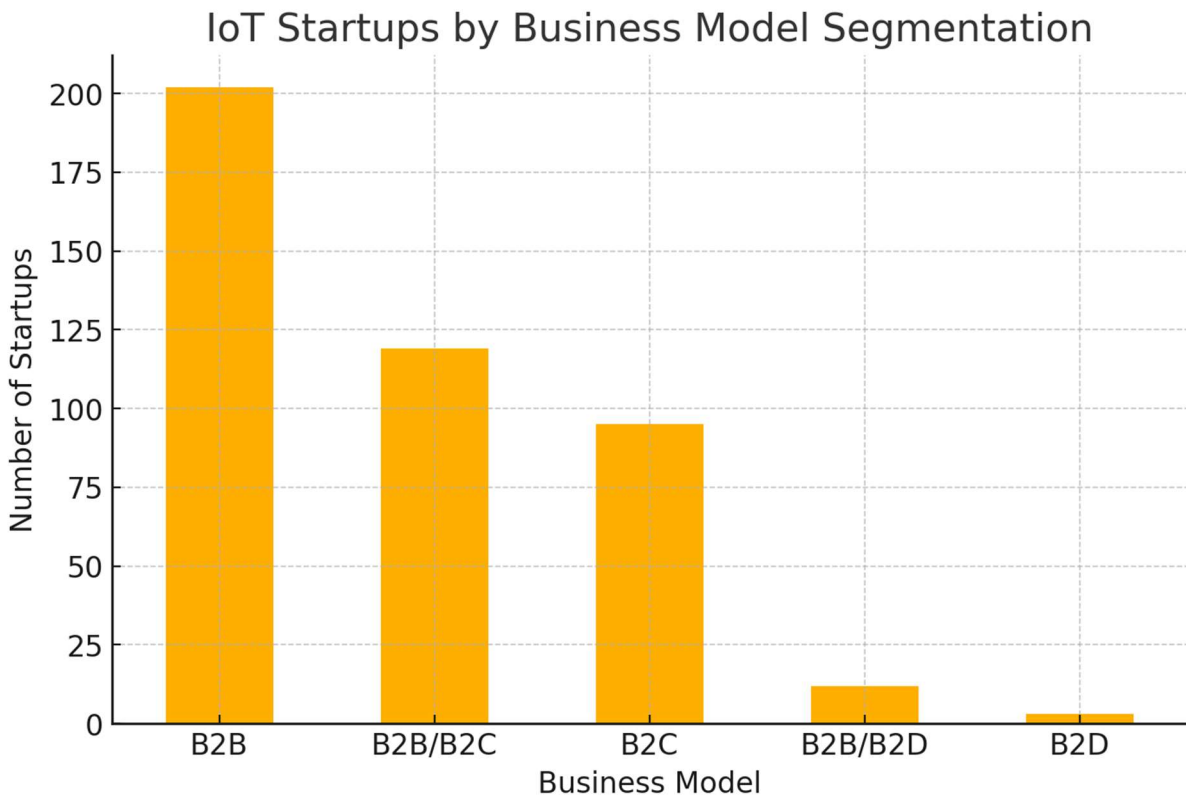


Figure 4: IoT Startups by Market based Business Model Segmentation (Last 5 years, sample size 465)

The dominance of B2B models in the IoT industry suggests that most IoT solutions are tailored for enterprise use rather than direct consumer applications. This trend is driven by the fact that businesses can justify the costs of IoT implementation more easily than individual consumers, as enterprises benefit from enhanced operational efficiency, data-driven decision-making, and cost reductions. In contrast, B2C IoT startups are less common, likely due to the significant challenges associated with consumer adoption, including high upfront costs, interoperability issues, data privacy concerns, and the need for strong customer support. Additionally, consumer IoT products often require seamless integration with existing ecosystems, which can be complex and resource-intensive. However, B2B/B2C hybrid models offer greater flexibility and may represent a growing trend, particularly for IoT platforms that cater to both enterprises and individual customers. These hybrid models allow companies to leverage enterprise-scale deployments while also offering consumer-facing applications, such as smart home integrations or wearable technology, potentially broadening their market reach and driving innovation in the IoT space.

While market-based business models (B2B, B2C, B2D) categorize IoT startups based on their target customers, framework-based business models define how a startup structures its value creation, revenue generation, and competitive strategy. These models are designed to guide IoT companies in choosing scalable and sustainable operational approaches.

The second graph illustrates the trends in IoT startups using framework-based business models such as the Value Net Model, MOP Model, DNA Model, Business Model Canvas, 2x2 Matrix Model, and Three-Dimensional Model. The data indicates that the Value Net Model dominated IoT startups in 2020 but has seen a sharp decline in recent years, suggesting that collaborative and network-driven business strategies are becoming less common. Conversely, the DNA Model, which is commonly applied in logistics and supply chain-focused IoT businesses, has shown resilience, with some recent startups still adopting it in 2024. Other models, such as the Business Model Canvas and Three-Dimensional Model, have remained relatively stable over time, reflecting their adaptability to different IoT industries.

The key difference between market-based and framework-based models is that market-based models define WHO a startup sells to, while framework-based models define HOW a startup operates. A B2B startup, for example, may use the MOP Model to integrate technology, policy, and industry-specific factors into its strategy, whereas a B2C startup may rely on the Business Model Canvas to develop a scalable consumer product roadmap. Thus, market-based models help classify startups by their customer approach, while framework-based models offer structural and strategic insights into business operations.

As IoT markets mature, startups must combine both perspectives, ensuring that their target audience aligns with an effective business structure. The declining number of startups using framework-based models in recent years suggests that new entrants are either relying on more flexible, customized business strategies or facing challenges in defining long-term operational models amid economic and regulatory uncertainties.

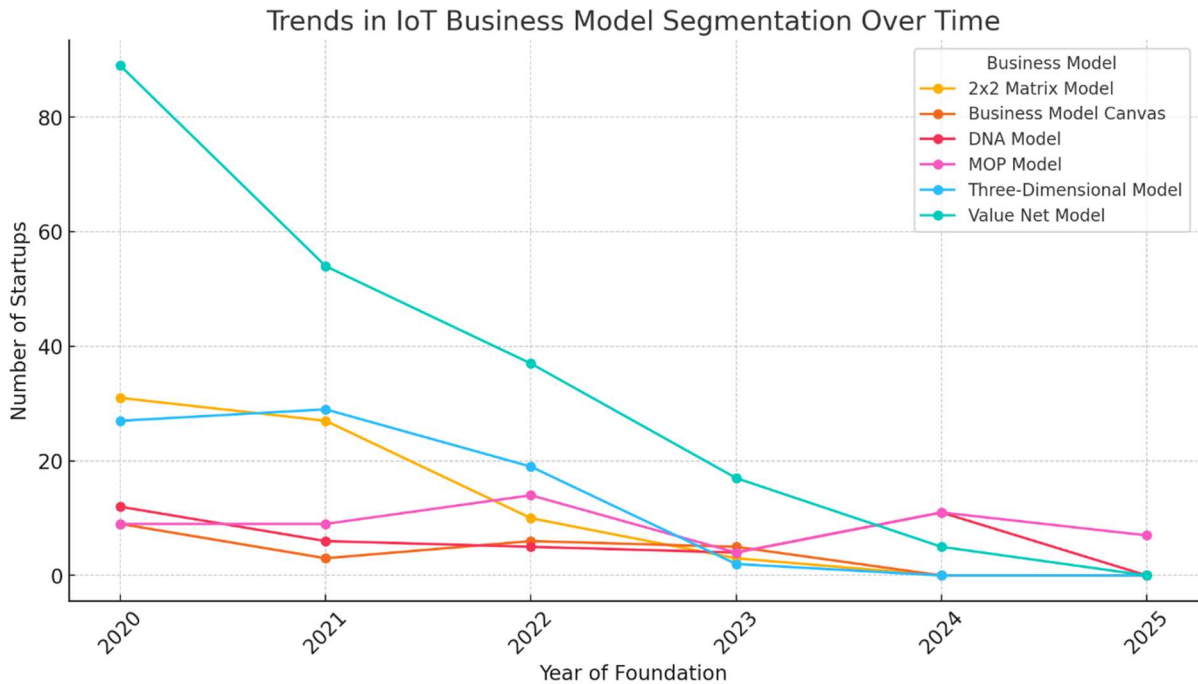


Figure 5: Trends in IoT Framework based Business Model Segmentation Over Time  
(Last 5 years, sample size 465)

The graph reveals a notable decline in the adoption of structured framework-based business models among IoT startups over the period from 2020 to 2025. In 2020, models such as the Value Net Model experienced high adoption, reflecting a period when many startups embraced collaborative, network-driven strategies. However, as the years progressed, there was a marked decrease in the use of this model. This decline may indicate that, amid increasing market consolidation and the rising dominance of larger corporations, smaller startups have found it less advantageous to rely on extensive value networks for their operations.

In contrast, the Business Model Canvas and the DNA Model have maintained a relatively stable presence in the IoT startup ecosystem. The Business Model Canvas, with its flexible and customizable approach, continues to be a popular choice, suggesting that many startups value the adaptability it offers in rapidly evolving market conditions. The DNA Model, which is often applied to startups operating in the logistics and supply chain sectors, has shown some fluctuations but even experienced a slight resurgence in 2024. This pattern may be driven by the growing demand for real-time data analysis and AI-driven logistics solutions, highlighting that specific industries still find structured frameworks beneficial.

Models such as the MOP Model and the Three-Dimensional Model, which integrate multiple dimensions like technology, industry, policy, and service delivery, saw a

decline particularly after 2022. This trend might be attributed to the increasing regulatory complexities and the pressure on startups to focus on quick execution and agile strategies rather than adhering to comprehensive, multi-layered frameworks. In a market where speed and adaptability are critical, the preference appears to be shifting toward leaner approaches that allow for faster pivoting in response to emerging challenges and opportunities.

The fundamental difference between market-based and framework-based business models also becomes evident in these trends. Market-based models (B2B, B2C, B2B/B2C hybrid, and B2D) concentrate on identifying and serving a specific customer segment. They define who the startup is targeting, whether enterprises, consumers, or developers. In contrast, framework-based models focus on how the startup operates internally—structuring its processes, strategic planning, and value creation. While market-based classifications determine the customer approach, framework-based models provide insight into the operational blueprint that underpins a startup's long-term strategy.

Overall, the observed trends from the second graph suggest that IoT startups are increasingly favoring flexibility and rapid adaptation over rigid adherence to complex business frameworks. While the market-based models continue to delineate customer segments and drive go-to-market strategies, the diminishing reliance on structured framework-based models indicates a shift towards agile, execution-focused approaches. This evolution in strategic orientation underscores the dynamic nature of the IoT landscape, where startups must balance customer demands with the need for operational efficiency and adaptability in an environment marked by rapid technological and regulatory change.

#### 3.1.4. Geographical Trends: Regional and Country-Level Distribution

Analyzing the geographical distribution of IoT startups reveals a strong dominance of **North America**, particularly the **United States**, followed by **Europe** and **Asia**. In analysis of the 2024 IoT startup landscape, supported by the database of emerging IoT companies, reveals significant geographical trends.

The United States maintains its leadership in IoT innovation and investment, accounting for 23% of global IoT revenue in 2024. This substantial share underscores the country's robust ecosystem supporting IoT startups and technological advancements (ABI Research, 2024). The database analysis highlights that a majority of U.S.-based IoT startups focus on cloud computing, AI-driven analytics, and industrial IoT applications, reinforcing the country's position as a leader in the sector.

The United Kingdom has emerged as a strong player in smart cities and industrial IoT. Government initiatives and a dynamic tech sector have propelled the integration of IoT solutions in urban infrastructure and industrial processes, fostering a conducive environment for IoT startups (Statista, 2024). According to the database findings, UK-based startups predominantly specialize in urban mobility, energy-efficient smart grid systems, and cybersecurity-enhanced IoT deployments.

Germany continues to focus on industrial automation and manufacturing IoT, aligning with its Industry 4.0 strategy. The country's strong industrial base and commitment to digital transformation have made it a hub for advanced automation (Straits Research, 2024). Database analysis confirms that German IoT startups are primarily engaged in predictive maintenance, connected manufacturing solutions, and AI-enhanced industrial monitoring systems.

These findings, derived from the IoT startup database, suggest that developed economies drive the IoT startup ecosystem, leveraging access to venture capital, technological expertise, and robust infrastructure. The concentration of IoT startups in these regions indicates the presence of well-established technology ecosystems, government support programs, and active investor networks. Furthermore, the regulatory environment in developed markets fosters innovation, with policies aimed at promoting data security, interoperability, and sustainable development.

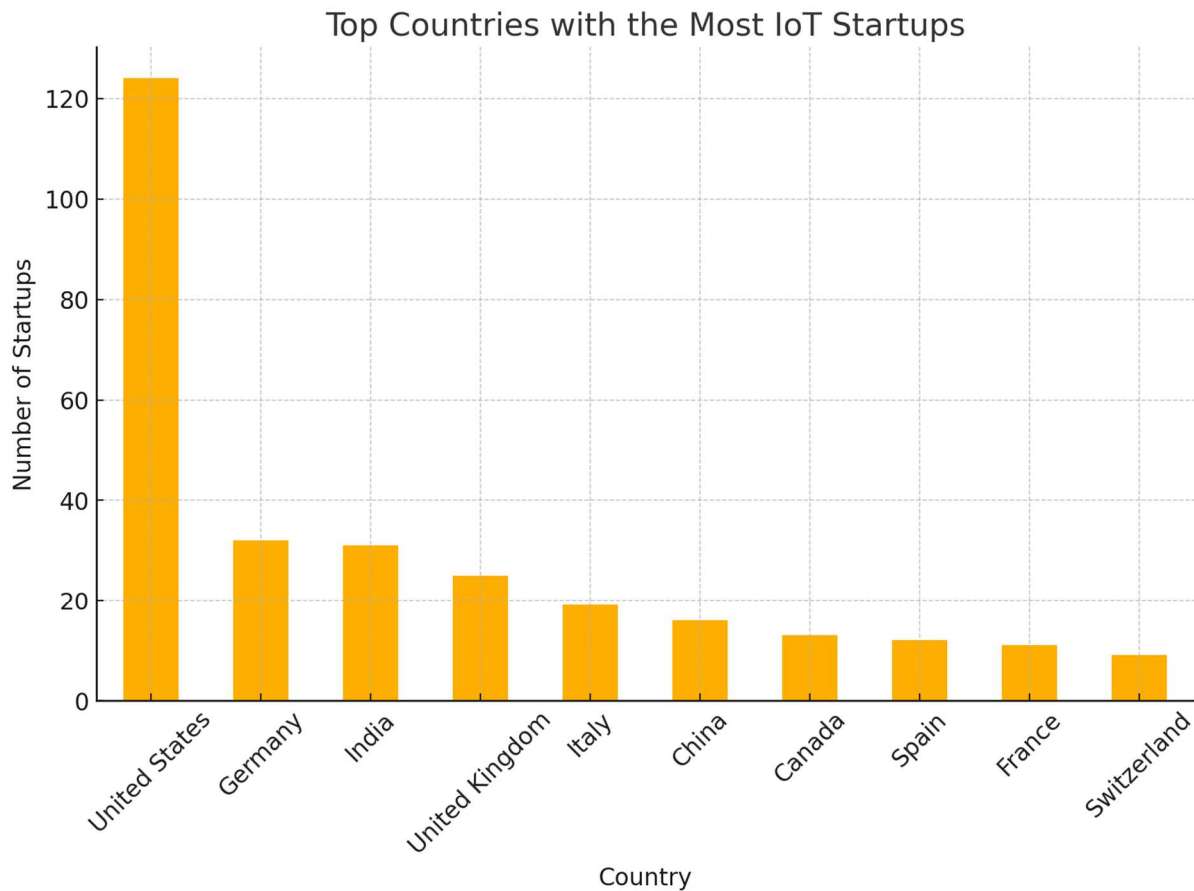


Figure 6: Top Countries with the Most IoT Startups (Last 5 years, sample size 465)

These patterns suggest that **developed economies drive the IoT startup ecosystem**, leveraging access to venture capital, technological expertise, and robust infrastructure. The concentration of IoT startups in these regions indicates the presence of well-established technology ecosystems, government support programs, and active investor networks. Furthermore, the regulatory environment in developed markets fosters innovation, with policies aimed at promoting data security, interoperability, and sustainable development.

Emerging markets, although underrepresented in the dataset, hold significant potential for IoT expansion. Countries in South America, Africa, and parts of Asia are experiencing increased adoption of IoT technologies, driven by factors such as urbanization, industrial digitization, and the need for smart infrastructure solutions. Future studies could focus on tracking the growth of IoT startups in these regions to assess their contribution to the global IoT landscape.

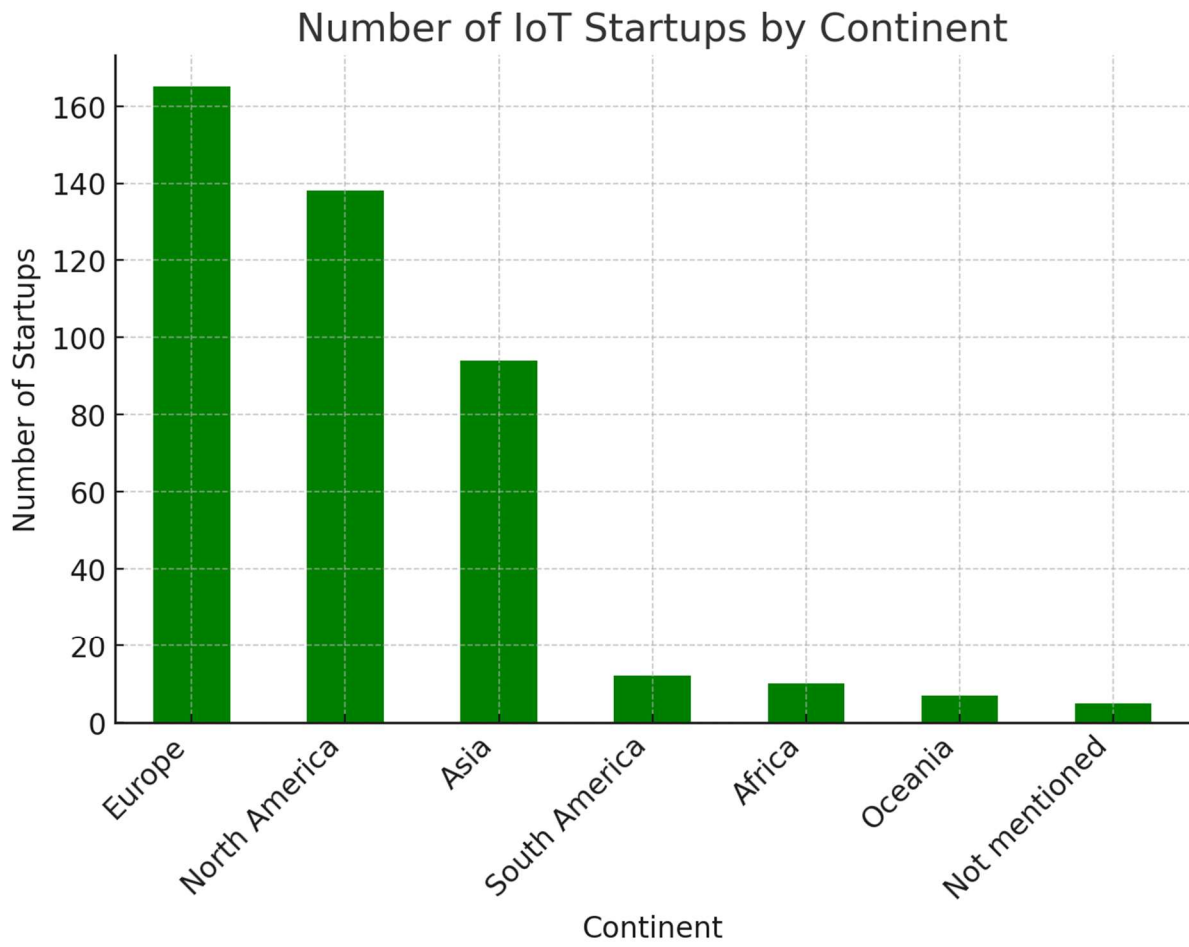


Figure 7: Number of IoT Startups by Continent (Last 5 years, sample size 465)

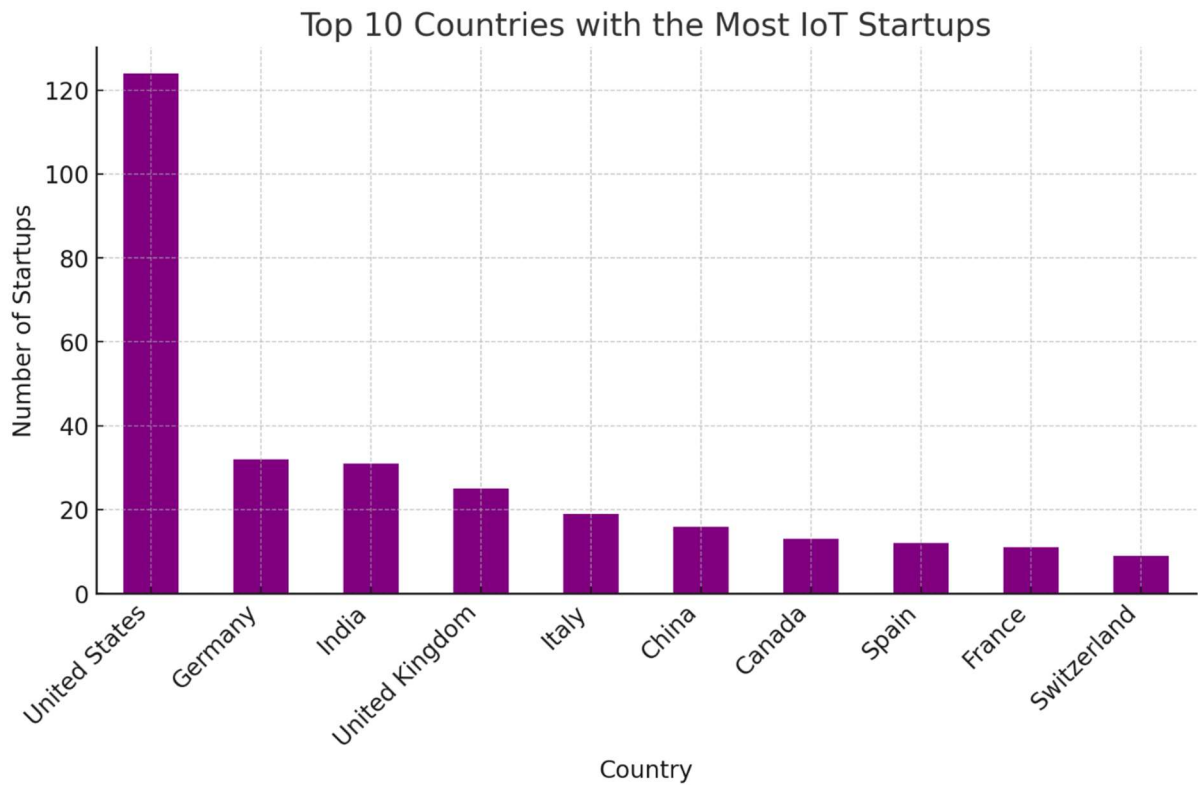


Figure 8: Top 10 Countries with the Most IoT Startups (Last 5 years, sample size 465)

### 3.1.5. Funding and Growth Patterns

Funding data provides insights into the financial strength and scalability of IoT startups. The analysis indicates that:

- **Higher funding correlates with larger employee sizes**, though some startups receive significant investments while maintaining small teams (suggesting capital-intensive R&D rather than workforce expansion).
- **Funding distribution varies significantly**, with some startups securing multi-million-dollar investments while others remain at lower funding levels.

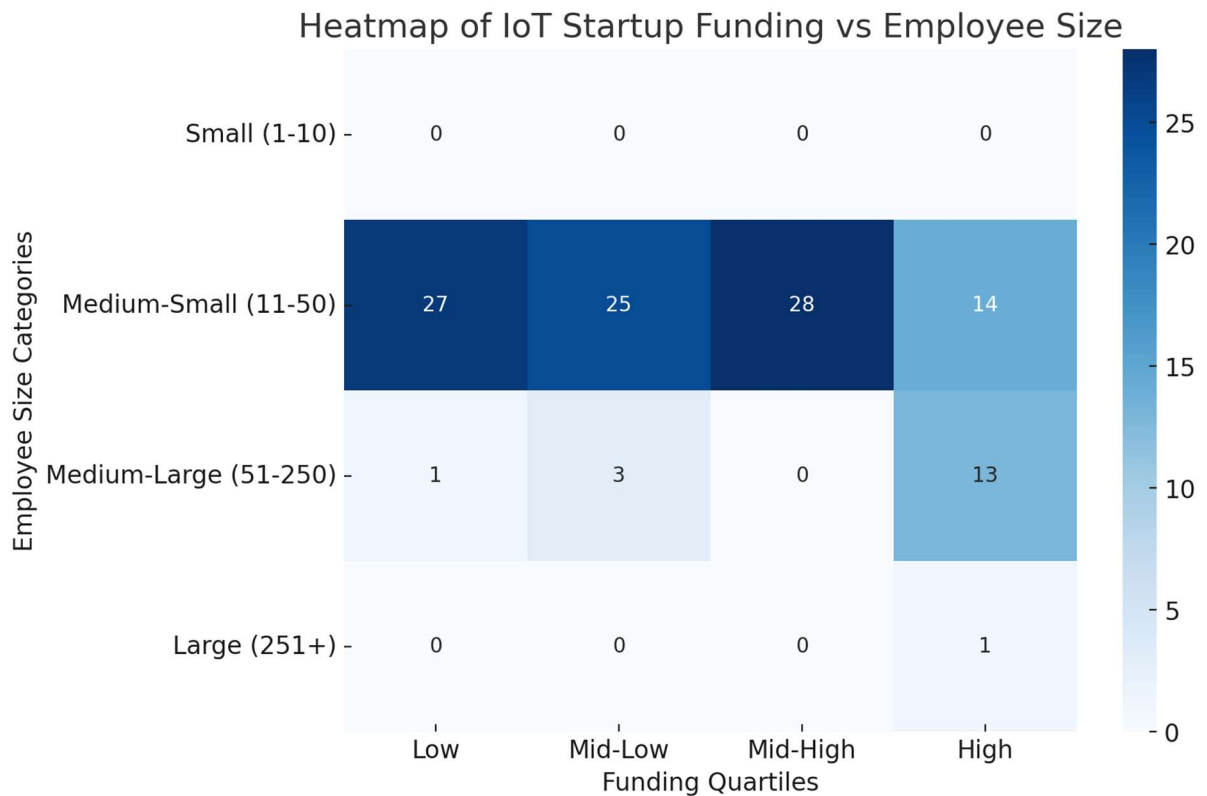


Figure 9: Heatmap of IoT Startup Funding vs Employee Size (Last 5 years, sample size 465)

The heatmap illustrates the relationship between IoT startup funding levels and employee size categories. Funding is divided into four quartiles—Low (bottom 25%), Mid-Low (25-50%), Mid-High (50-75%), and High (top 25%)—while employee size is categorized into Small (1-10 employees), Medium-Small (11-50), Medium-Large (51-250), and Large (251+). The numbers within the heatmap indicate the count of startups within each funding-employee combination. The data reveals that higher funding generally correlates with larger employee sizes, though some highly funded startups maintain small teams, likely due to capital-intensive R&D. The majority of startups fall within mid-range funding and employee categories, suggesting a balance between financial backing and scaling. This pattern reinforces the idea that IoT startup funding is highly selective, favoring firms with strong market potential or technological innovation, while disparities in funding highlight the challenges some startups face in securing investment.

### 3.1.6. Acquisition Trends: Industry and Regional Insights

An analysis of acquisition trends in the IoT sector shows that **Infrastructure & Networks startups** are the most frequently acquired. This reflects a strong demand for automation, digital infrastructure, and energy efficiency solutions.

From a geographical perspective, **most acquisitions occur in Europe and Asia**, where established companies actively acquire emerging startups to enhance their technological capabilities and expand their market presence. In contrast, North America shows lower acquisition activity, which may be due to different investment strategies or market dynamics.

However, the overall number of acquired startups remains relatively low because the data focuses only on **companies founded in the last five years**. This highlights several key factors:

- **Longer development cycles for IoT startups** – Many startups take longer to reach the stage where they become attractive for acquisition.
- **Investor focus on scalability** – Corporations and venture capitalists may prioritize startups with proven resilience and successful pilot projects, reducing the number of acquisitions among younger companies.
- **Competition from alternative growth strategies** – Instead of acquisitions, some corporations develop in-house IoT solutions or form strategic partnerships, decreasing the need to buy startups.

These trends confirm that acquisitions remain a critical tool for scaling IoT innovations, particularly in logistics, smart infrastructure, and energy sectors. Companies seek to integrate emerging technologies to enhance operational efficiency, reduce costs, and unlock new revenue streams, while startups benefit from acquisitions by gaining the financial and operational resources needed to scale and enter new markets.

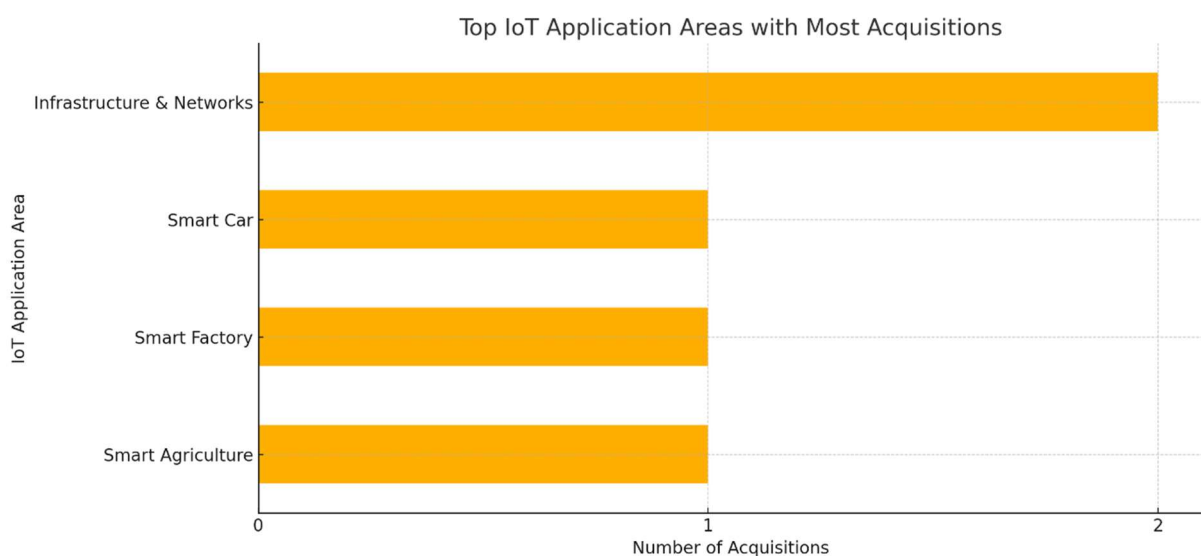


Figure 10: Top IoT Application Areas with Most Acquisitions (Last 5 years, sample size 465)

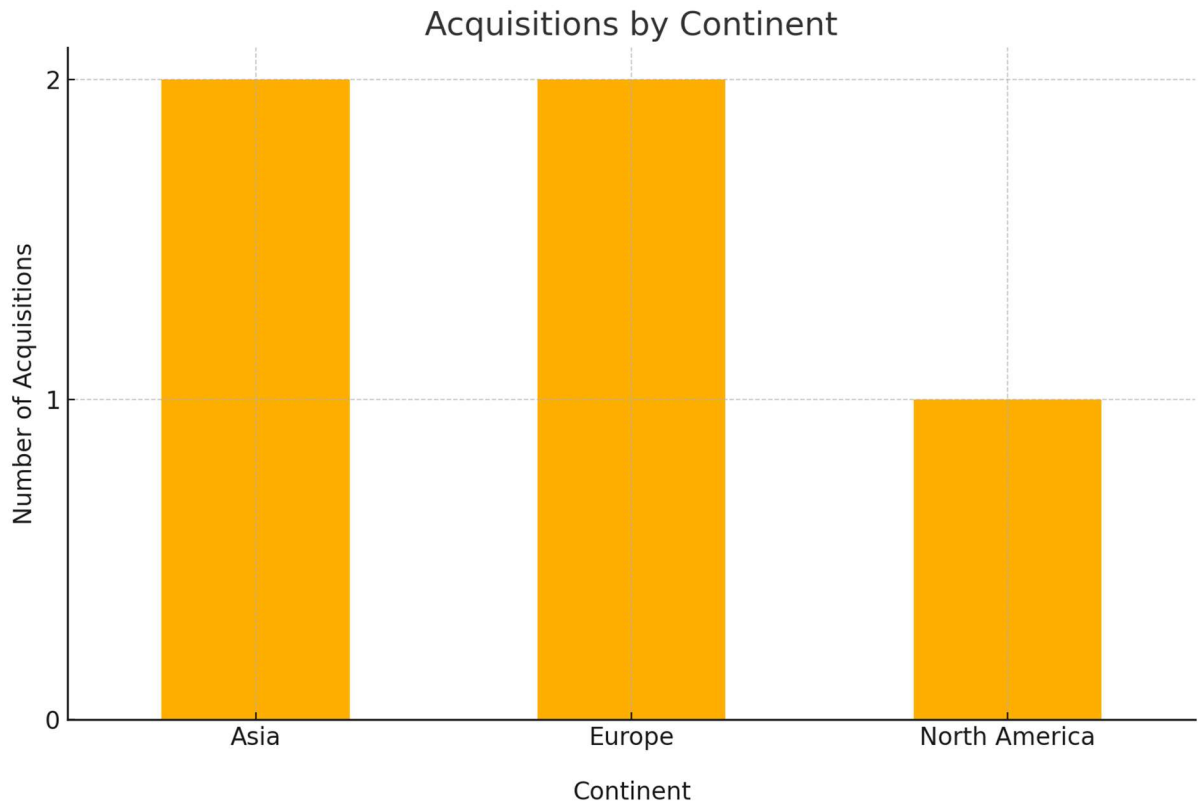


Figure 11: Acquisitions by Continent (Last 5 years, sample size 465)



## 4 Business models for the Internet of Things Companies

The advent of the Internet of Things (IoT) has paved the way for new business opportunities by interconnecting physical objects through sensors and networks. IoT's ubiquity and pervasiveness necessitate the development of innovative business models to harness its potential. Traditional business models often fall short of addressing the unique demands of IoT services, leading to the emergence of various specialized models. This chapter explores several business models tailored for IoT, including the MOP Model, DNA Model, Value Net Model, and others, highlighting their structures, components, and applications.

### 4.1. MOP Model

The MOP Model, developed by Li and Xu (2013), is a multidimensional framework designed to analyze and structure IoT businesses. This model integrates four key dimensions—technology, industry, policy, and strategy—ensuring a holistic approach to IoT business development (Li & Xu, 2013). By incorporating these interconnected dimensions, the MOP Model aids in identifying challenges and opportunities in IoT business environments:

- **Technology Dimension:** Encompasses advancements in IoT hardware (sensors, devices, and connectivity) and software (cloud computing, AI, and big data analytics), which are crucial for IoT deployment (Gubbi et al., 2013). Emerging trends such as edge computing, blockchain for IoT security, and AI-driven automation further enhance this dimension (Miorandi et al., 2012).
- **Industry Dimension:** Focuses on sector-specific IoT applications, such as smart healthcare, industrial IoT (IIoT), smart cities, connected transportation, and agritech, ensuring adaptability across different industries (Porter & Heppelmann, 2014).
- **Policy Dimension:** Evaluates regulatory compliance, cybersecurity laws, and data protection policies that govern IoT businesses globally. For instance, the GDPR (General Data Protection Regulation), California Consumer Privacy Act (CCPA), and NIST (National Institute of Standards and Technology)

Cybersecurity Framework heavily impact IoT strategy in Europe and the U.S. (Weber, 2015).

- **Strategy Dimension:** Involves strategic planning, business model innovation, and market positioning to ensure IoT solutions align with industry trends and consumer needs (Baines et al., 2017). Additionally, businesses adopting IoT must consider scalability, interoperability, and sustainability in their strategies (Wortmann & Flüchter, 2015).

This model provides a systematic approach to integrating IoT into businesses while addressing technological feasibility, regulatory constraints, and strategic objectives. Companies such as Siemens, IBM, and Huawei have successfully leveraged the MOP Model to develop robust IoT ecosystems.

## 4.2. DNA Model

Proposed by Sun et al. (2012), the DNA Model is a conceptual framework tailored for smart logistics and supply chain optimization using IoT. The model structures business model development through three core components—design, needs, and aspirations—which function as fundamental "DNA blocks" at every operational level (Sun et al., 2012).

- **Design:** Refers to the system architecture, platform interoperability, and functional aspects of IoT solutions, ensuring scalability and efficiency in logistics networks (Melo et al., 2020). Modern digital twins, AI-based predictive analytics, and autonomous supply chain systems further optimize the design phase (Hofmann & Rusch, 2017).
- **Needs:** Represents the demands of businesses (e.g., predictive analytics, automation, and cost-efficiency) and end-users (e.g., real-time tracking, seamless delivery experience) (Wamba et al., 2020). The rise of **just-in-time** (JIT) logistics and AI-driven demand forecasting underscores the importance of aligning supply chains with dynamic market conditions.
- **Aspirations:** Encompasses the long-term objectives of IoT adoption, such as sustainability, operational resilience, and enhanced data-driven decision-making (Weinberger et al., 2016). The circular economy and green logistics initiatives increasingly influence aspirations in smart logistics.

The DNA Model is particularly beneficial in supply chain digitization, where IoT-enabled RFID tracking, smart warehousing, blockchain for supply chain transparency, and AI-driven logistics management are key to optimizing operations.

### 4.3. Value Net Model

Developed by Qin and Yu (2015), the Value Net Model is a customer-centric framework tailored for telecommunications, smart cities, and IoT ecosystems. This model emphasizes collaboration, resource integration, and value co-creation, ensuring optimal service delivery in IoT-driven markets (Qin & Yu, 2015).

- **Customer-Centered Strategy:** IoT service models (e.g., smart home automation, personalized healthcare monitoring, and industrial IoT) are designed to enhance customer experiences (Porter & Heppelmann, 2014). New trends such as hyper-personalized IoT solutions, voice-assisted AI, and real-time user feedback loops reinforce this focus.
- **Information Sharing:** Transparent data exchange among IoT devices, cloud platforms, and stakeholders improves decision-making and service customization (Ray, 2016). Advances in secure data-sharing protocols and federated learning in AI enhance this aspect (Zhang et al., 2018).
- **Resource Integration:** Combines hardware (IoT sensors), software (AI-driven analytics), and human expertise (IT professionals, engineers, and UX designers) to optimize IoT ecosystems (Weinberger et al., 2016).

This model fosters a collaborative IoT environment, where companies leverage shared data and services to maximize customer satisfaction and business efficiency. Companies like Cisco, Ericsson, and Nokia have successfully adopted this model for IoT-driven service networks.

### 4.4. Business Model Canvas

The Business Model Canvas, utilized by several researchers including Bucherer & Uckelmann (2011) and Dijkman et al. (2015), is a widely adopted framework for designing IoT business models. The canvas includes nine key components:

- **Key Partners:** Identifies the essential partners needed to deliver IoT services, such as software developers, data analysts, and device manufacturers. IoT service providers collaborate with hardware manufacturers, software developers, and cloud infrastructure providers (Wortmann & Flüchter, 2015). Strategic partnerships with telecom providers (e.g., AT&T, Vodafone) and big tech (e.g., Google, Amazon, Microsoft) are crucial.
- **Key Activities:** Encompasses the core activities required for IoT service delivery, including product development, platform management, resource

device manufacturing, data processing, network management, cybersecurity, and AI integration (Li et al., 2018).

- **Key Resources:** Lists of the critical resources, such as software, information, and customer databases, necessary for IoT operations.
- **Value Propositions:** Defines the unique value offered by IoT services, focusing on convenience, performance, and customization.
- **Customer Relationships:** Describes the type of relationships established with customers, including co-creation and self-service models.
- **Channels:** Outlines the channels through which IoT services are delivered to customers.
- **Customer Segments:** Identifies the target customer segments for IoT services, such as mobile users and businesses.
- **Cost Structure:** Details the cost components involved in delivering IoT services, including IT infrastructure and operational costs.
- **Revenue Streams:** Specifies the revenue generation methods, such as subscription fees and usage charges.

The Business Model Canvas provides a structured approach to developing and analyzing IoT business models, ensuring that all critical aspects are covered.

## 4.5. 2x2 Matrix Dimension Model

The 2x2 Matrix Dimension Model, introduced by Leminen et al. in 2012, is used in the automotive industry to explore B2C solutions through IoT technology. This model provides a framework for understanding the interactions between various business and technological dimensions. The 2x2 matrix is structured around four key areas:

- **Internal vs. External:** This axis differentiates between resources and processes that are internal to the organization and those that involve external stakeholders, such as partners and customers. For example it differentiates between in-house IoT development (e.g., **Tesla's Autopilot**) and partnerships (e.g., **Google's Android Auto**) (Leminen et al., 2012).
- **Product vs. Service:** This axis contrasts tangible IoT products (e.g., smart devices) with intangible services (e.g., data analytics and support) (Ray, 2016).

By mapping out these dimensions, companies can identify strategic opportunities and challenges in the IoT landscape. This model helps businesses understand the balance between product offerings and service provisions while considering internal capabilities and external collaborations.

## 4.6. Three-Dimensional Model

Proposed by Chan in 2015, the Three-Dimensional Model offers a comprehensive view of the different elements involved in IoT business operations. This model includes multiple layers, each addressing a specific aspect of the business ecosystem:

1. **Collaborators:** Identifies key partners and stakeholders involved in the IoT ecosystem, including technology providers, service integrators, and regulatory bodies.
2. **Networks:** Focuses on the communication and data exchange networks that enable IoT functionalities, ensuring seamless connectivity and interoperability.
3. **Tactics:** Encompasses the strategic and operational tactics employed to deliver IoT services, such as marketing strategies and customer engagement practices.
4. **Inputs:** Refers to the resources and inputs required for IoT operations, including hardware, software, and human expertise.
5. **Service/Processing/Packaging:** Addresses the processes involved in delivering IoT services, from data processing and analysis to packaging and presenting the final service to customers.
6. **Benefits:** Highlights the benefits and value propositions offered by IoT services, focusing on customer satisfaction and operational efficiency.
7. **Strategy:** Involves the overarching business strategy that aligns IoT initiatives with organizational goals and market demands.
8. **Content/Information Product:** Refers to the data and information products generated through IoT operations, emphasizing their role in decision-making and value creation.

The Three-Dimensional Model provides a detailed framework for managing and optimizing the various components of IoT business operations, ensuring a cohesive and integrated approach.

## 4.7. Analysis of IoT Startups Using Business Models

This chapter presents an analysis of IoT startups using established business models, leveraging the structured database of startups. The analysis categorizes startups based on their alignment with the MOP Model, DNA Model, Value Net Model, Business Model Canvas, 2x2 Matrix Dimension Model, and the Three-Dimensional Model. Updated visualizations, including bar charts and stacked bar charts, illustrate the distribution of business models, revenue patterns, and regional adoption trends.

### 4.7.1. Business Model Distribution

The first step in the analysis is to visualize the distribution of IoT startups across different business models. The following bar chart illustrates the number of startups categorized under each business model:

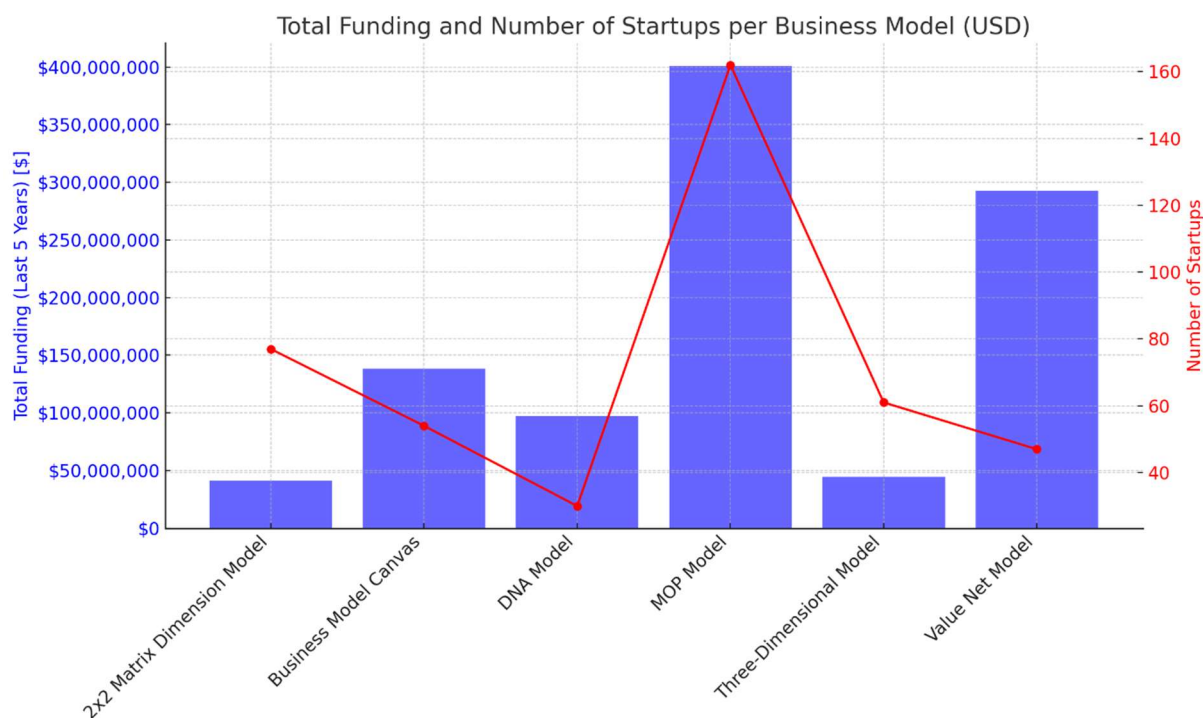


Figure 12: Total Funding and Number of Startups per Business Model  
(Last 5 years, sample size 465)

The dominance of the MOP (Market-Organization-Product) Model among startups in Infrastructure & Networks, Smart Grid, and Smart Metering sectors underscores the complexity of large-scale, policy-driven IoT applications. These domains require strategic approaches that integrate multiple dimensions, including regulatory compliance, infrastructure development, and technological scalability. The MOP Model's emphasis on aligning market needs, organizational capabilities, and product development aligns well with the high dependency of these sectors on government policies, industry standards, and interoperability frameworks (Wirtz et al., 2019). Given the extensive investment and regulatory oversight involved in smart infrastructure projects, startups operating in these areas must adopt a multidimensional strategy to navigate both public and private sector demands effectively.

In contrast, the DNA (Dynamic, Need-driven, Adaptive) Model is particularly prevalent in Smart Logistics and Smart Retail, reflecting the importance of agility and customization in these industries. Logistics and retail require high adaptability due to fluctuations in consumer demand, supply chain disruptions, and the continuous evolution of e-commerce (Ghezzi & Cavallo, 2020). The DNA Model's core principles emphasize dynamic strategic decision-making and the ability to respond quickly to technological advancements, making it a natural fit for these fast-paced environments. Startups in this space must continuously innovate and leverage real-time data analytics, automation, and AI-driven decision-making to maintain competitive advantage.

For startups developing multi-application platforms, the Value Net Model appears to be the preferred approach. This suggests a strong focus on interconnectivity and customer-centric ecosystems, where value creation is distributed across multiple stakeholders (Al-Debei & Avison, 2010). The Value Net Model, originally introduced by Brandenburger and Nalebuff (1996), highlights how businesses can simultaneously collaborate and compete to generate mutual benefits. In the context of IoT, where interoperability and ecosystem-based approaches are crucial, this model provides a structured way to balance partnerships, technological integrations, and user engagement. Startups in this domain often operate at the intersection of various industries, requiring strategic positioning to maximize network effects and platform scalability.

The Business Model Canvas (BMC) remains one of the most widely applicable frameworks, particularly among startups offering Hardware, Software, and Services. Its strong presence in eHealth and Wearable IoT solutions reinforces its versatility in structuring business strategies across diverse operational models (Osterwalder & Pigneur, 2010). eHealth startups, for example, face unique challenges related to regulatory constraints, data privacy, and cross-sector collaboration with healthcare providers. The BMC allows them to visually map out critical components such as key partners, revenue streams, and customer segments, facilitating strategic alignment. Similarly, Wearable IoT startups benefit from this framework by identifying value propositions that balance technology, design, and user experience.

A more specialized approach is seen with the 2x2 Matrix Dimension Model, which is particularly relevant for Smart Car startups. This reflects the necessity of balancing product offerings with service-oriented business strategies. The automotive industry is undergoing a fundamental shift toward mobility-as-a-service (MaaS), where ownership models are gradually being replaced by subscription-based and shared mobility solutions (Teece, 2010). The 2x2 Matrix Dimension Model provides a

structured way to categorize business models based on these evolving dynamics, helping startups determine their positioning within the industry.

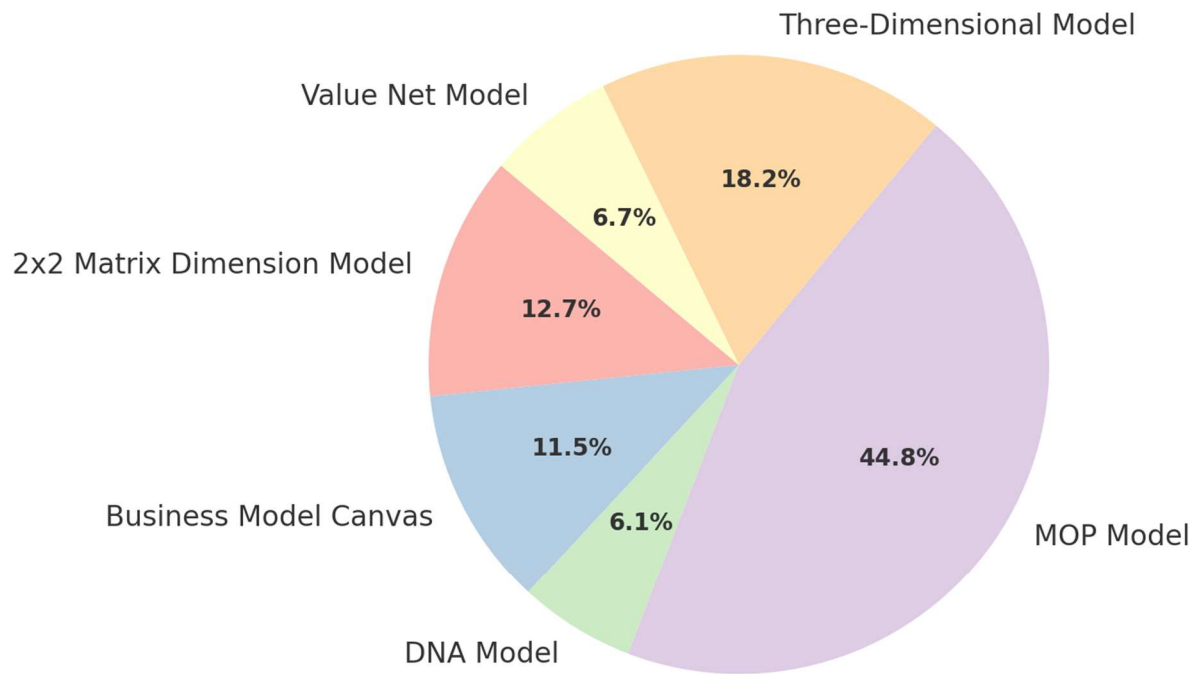
Finally, the Three-Dimensional Model is widely adopted in Smart Agriculture, emphasizing the increasing need for collaborative networks and cross-industry integration. Agriculture IoT solutions rely heavily on data-driven decision-making, precision farming, and ecosystem-level partnerships involving farmers, agritech firms, and governmental bodies (Klerkx et al., 2019). The Three-Dimensional Model's emphasis on interconnected networks, scalability, and integration across value chains makes it particularly well-suited for startups in this sector, where technology adoption is closely tied to economic incentives and policy support.

These observations suggest that business model choices in IoT startups are strongly influenced by industry characteristics, regulatory environments, and the need for technological adaptability. While some models, like the BMC, are flexible enough to apply across multiple sectors, others, such as the Value Net and Three-Dimensional Models, are tailored to specific ecosystem-driven or cross-sectoral opportunities. The strategic selection of business models is, therefore, critical for startups aiming to scale efficiently and achieve long-term sustainability in the rapidly evolving IoT landscape.

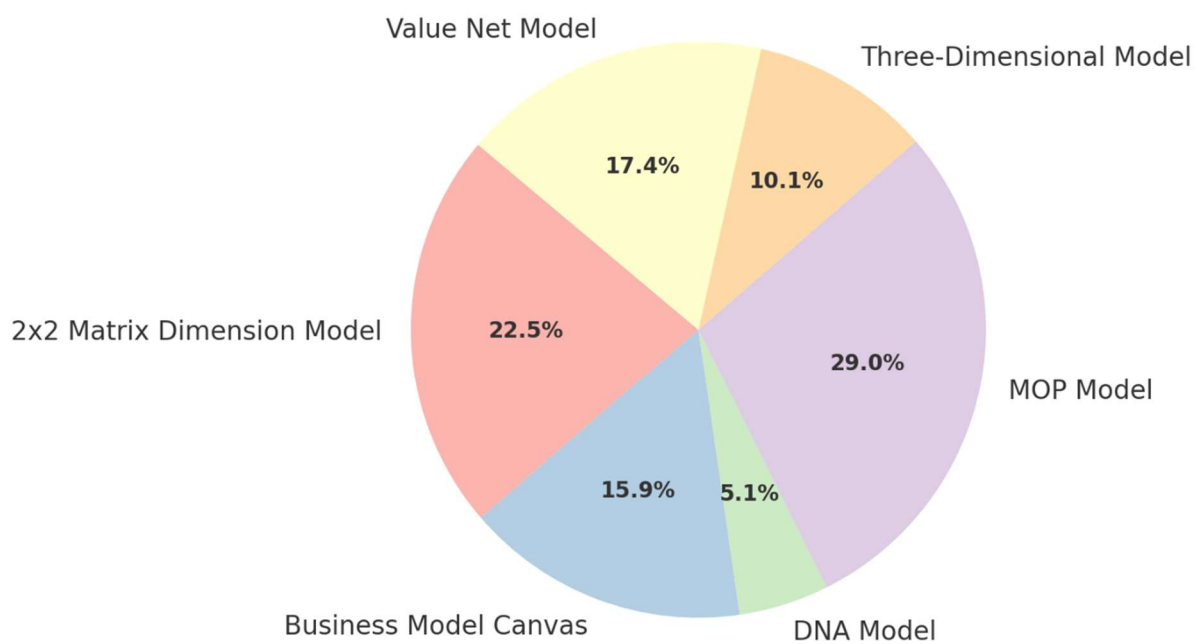
#### 4.7.2. Regional Analysis of Business Models

Understanding how business models vary across regions provides insight into market maturity and regulatory impacts:

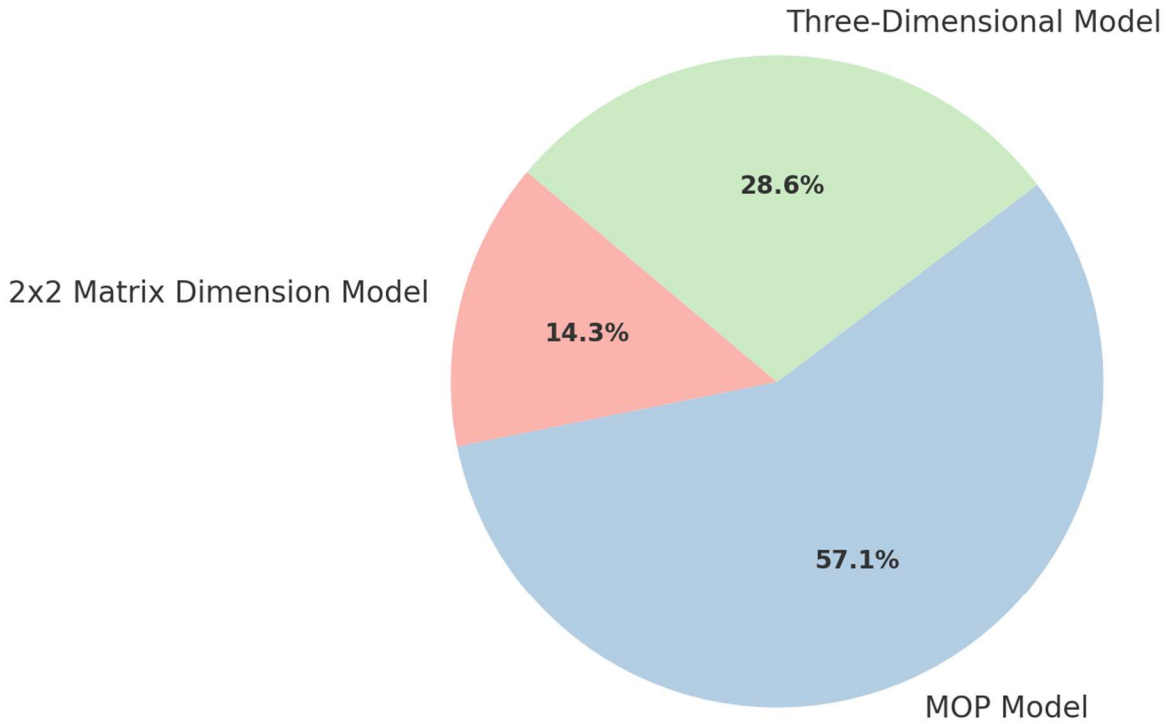
### Business Model Adoption in Europe



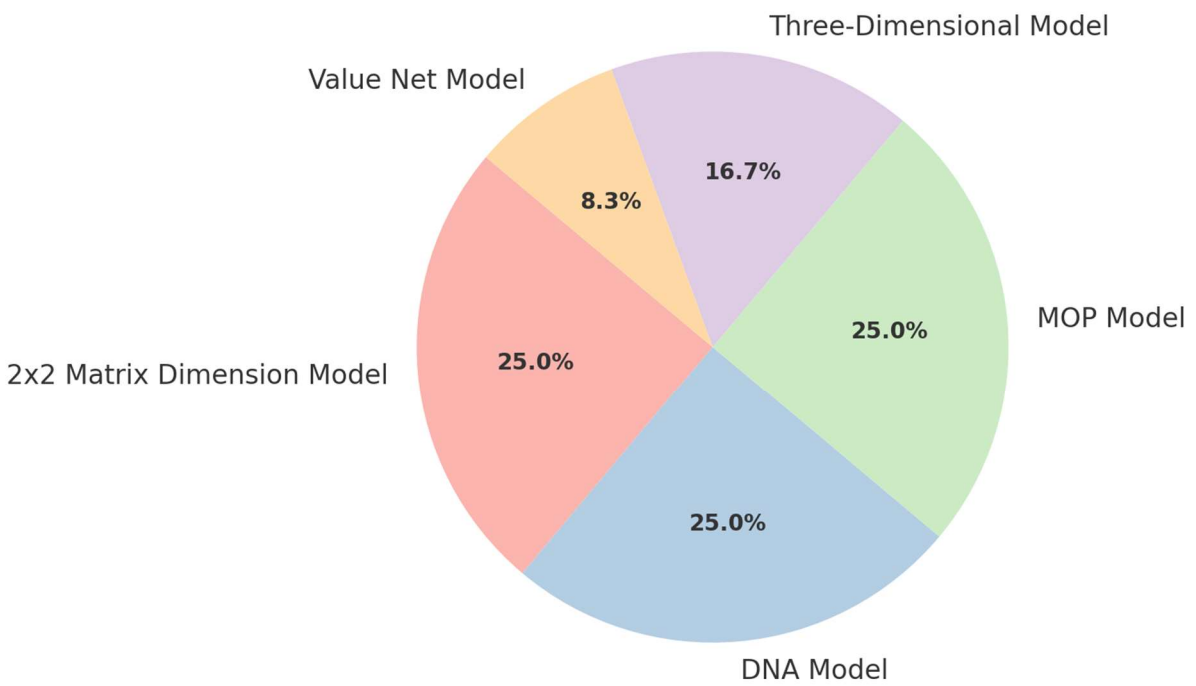
### Business Model Adoption in North America



### Business Model Adoption in Oceania



### Business Model Adoption in South America



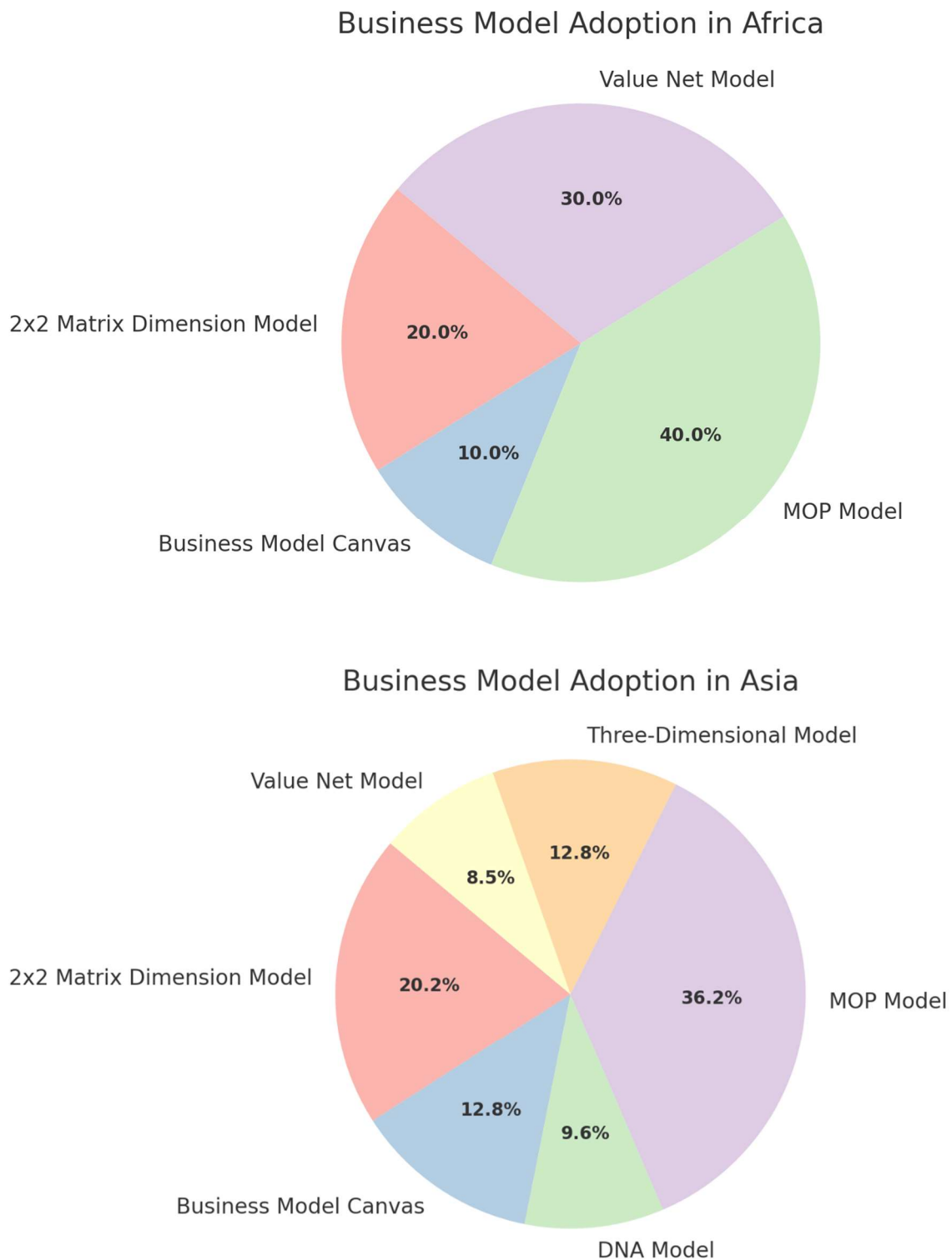


Figure 13: Business Model Adoption in Different Regions (Last 5 years, sample size 465)

North America exhibits a strong inclination toward the MOP Model (29%), suggesting a significant focus on policy-driven and infrastructure-heavy IoT solutions. This aligns with existing literature on IoT business models in developed economies, where large-scale investments in smart cities, industrial IoT, and cybersecurity compliance shape the landscape (Weber et al., 2020). The notable presence of the 2x2 Matrix Dimension Model (22.5%) further highlights a balanced approach between product and service strategies, which is essential in an environment driven by both technological innovation and regulatory considerations (Porter & Heppelmann, 2015). Given the region's advanced digital ecosystem, these trends suggest that North American IoT startups are strategically leveraging government initiatives (e.g., smart infrastructure funding) while ensuring business scalability through service-oriented revenue streams (Chesbrough, 2020).

In Europe, the dominance of the MOP Model (44.8%) reinforces the well-documented regulatory-driven nature of the market, particularly in smart infrastructure, energy solutions, and sustainability initiatives. The European Union's stringent data protection laws (e.g., GDPR) and climate-focused policies (e.g., the European Green Deal) necessitate business models that can navigate complex compliance requirements (Westerlund, Rajala, & Leminen, 2014). The notable presence of the Three-Dimensional Model (18.2%) suggests that European IoT startups frequently operate within intricate business ecosystems, leveraging partnerships between corporations, public institutions, and technology providers. This complexity is characteristic of a market that prioritizes long-term viability and structured value chains rather than rapid, consumer-driven adoption (Rong et al., 2015).

Asia demonstrates strong adoption of the MOP Model (36.2%), reflecting the region's focus on infrastructure-heavy IoT solutions, particularly in China, Japan, and South Korea. This trend is supported by extensive government-backed IoT initiatives, such as China's smart manufacturing policies and Japan's Society 5.0 vision, which emphasize large-scale deployments in industrial automation and smart cities (Li, Da Xu, & Zhao, 2018). The 2x2 Matrix Dimension Model (20.2%) follows closely, indicating an emphasis on integrating IoT within automotive and manufacturing sectors—industries where Asia maintains a global competitive edge. Unlike Europe, where regulatory compliance is the primary driver, Asia's IoT market appears more geared toward industrial efficiency and technological leadership, reinforcing the

literature's classification of Asia as a hub for advanced manufacturing-driven IoT business models (Jia, Klotz, & Verma, 2021).

South America presents an even distribution among the MOP Model, DNA Model, and 2x2 Matrix Dimension Model (each 25%), suggesting an emerging but diverse IoT market. This balanced approach reflects the coexistence of different economic realities within the continent, where some countries prioritize government-driven infrastructure projects (MOP Model), while others explore adaptive, flexible business strategies (DNA Model) to overcome resource constraints (Amit & Zott, 2012). The presence of the 2x2 Matrix Dimension Model suggests that startups are seeking scalable business models that integrate product and service offerings, which is particularly relevant in economies where IoT adoption is still developing. Compared to more mature IoT markets, South America appears to be in a formative stage, where different business models are tested to determine which approach yields the highest return on investment (Parker, Van Alstyne, & Choudary, 2016).

Oceania exhibits the most concentrated reliance on the MOP Model (57.1%), indicating a strong preference for large-scale, policy-driven IoT projects. This aligns with Australia and New Zealand's emphasis on nationwide smart infrastructure programs, particularly in sectors like agriculture, environmental monitoring, and public safety (Leminen, Westerlund, & Rajahonka, 2017). The substantial presence of the Three-Dimensional Model (28.6%) suggests that multi-stakeholder collaboration plays a key role in IoT business strategies within the region. Literature on IoT ecosystems frequently highlights Oceania's unique approach to innovation, where government agencies, universities, and private companies often collaborate to drive technology adoption. This structured, partnership-based strategy contrasts with the more competitive and market-driven IoT environments observed in North America and Asia (Ghazawneh & Henfridsson, 2013).

Africa's IoT market shows the highest proportion of MOP Model (40%) startups, followed by the Value Net Model (30%), suggesting a blend of regulatory-driven approaches and network-based business ecosystems. Given Africa's diverse economic conditions and infrastructure challenges, the dominance of the MOP Model likely reflects government-led digital transformation efforts, such as smart city projects and national IoT policies aimed at improving public services (Ndemo & Weiss, 2017). Meanwhile, the significant presence of the Value Net Model aligns with research indicating that African startups often rely on network-based strategies to build scalable, collaborative business models. This is particularly relevant in

industries like mobile finance and agritech, where IoT solutions frequently depend on extensive partnerships between telecom operators, financial institutions, and international development organizations (Peppard & Rylander, 2006).

Overall, the distribution of IoT business models across regions underscores the strong influence of economic maturity, regulatory frameworks, and industrial priorities. Developed markets like North America and Europe exhibit structured, compliance-driven approaches, while Asia focuses on industrial efficiency and technological dominance. Emerging regions such as South America and Africa, on the other hand, showcase a more experimental and adaptive approach, where multiple business models coexist as the market finds its optimal structure. This confirms broader academic findings that IoT business models are not only technology-driven but also deeply shaped by regional economic and policy environments (Teece, 2010).

## 5 Conclusion

The rapid evolution of the Internet of Things (IoT) startup ecosystem underscores its pivotal role in transforming industries by enhancing efficiency, connectivity, and data-driven decision-making. This thesis has explored the business models that underpin IoT startups, their offerings, and the challenges and opportunities they face. The findings reveal that subscription-based models, data monetization strategies, and hybrid approaches are central to the sustainability and scalability of IoT startups. Additionally, regional variations in business model adoption highlight the influence of regulatory environments, investor ecosystems, and market needs.

### 5.1. Limitations and Challenges in Researching IoT Startups

While this study offers a comprehensive exploration of IoT startups, certain limitations exist:

#### **Data Accessibility**

Despite the extensive availability of startup-related data on platforms such as Crunchbase, Dealroom, and PitchBook, obtaining complete and accurate information remains a challenge. Many IoT startups, particularly early-stage companies, may not fully disclose their financial or operational details, either due to confidentiality concerns or a lack of regulatory requirements mandating public reporting. This issue is further exacerbated in regions with stringent data privacy laws, such as the European Union's General Data Protection Regulation (GDPR) or China's Cybersecurity Law, which limit access to corporate and customer data.

Furthermore, the reliance on self-reported data in startup databases introduces the risk of inconsistencies and potential bias. Founders and investors may selectively disclose information to enhance their market positioning, which could lead to overestimated valuations or exaggerated growth metrics. As a result, analyzing global trends comprehensively becomes more complex, particularly when comparing startups across different markets with varying levels of transparency.

#### **Rapid Technological Change**

The IoT industry is characterized by rapid technological advancements, making it challenging to ensure that research remains current. By the time data is collected,

analyzed, and published, new innovations may emerge, reshaping the competitive landscape. Key trends such as the convergence of artificial intelligence (AI) with IoT, the increasing adoption of blockchain for device security, and the deployment of 5G networks for enhanced connectivity are continuously evolving. These developments may significantly impact the relevance of findings if they are not incorporated into the analysis in real time.

Additionally, IoT startups must navigate an environment where hardware and software standards are constantly shifting. Protocols such as Matter (for smart home interoperability) or new cybersecurity frameworks may gain traction after research has been conducted, influencing startup strategies and market positioning. This fluidity in the technological landscape means that any study on IoT startups should be viewed as a snapshot rather than a definitive long-term assessment.

### **Limited Use of IoT Data**

One of the most significant challenges in the IoT ecosystem is the underutilization of the vast amounts of data generated by connected devices. Estimates suggest that less than 1% of IoT data is currently being actively used for decision-making or optimization. The sheer volume and velocity of data present both a technical and business challenge for startups seeking to extract actionable insights.

Several factors contribute to this limitation:

- 1. Data Fragmentation** – IoT devices are produced by numerous manufacturers using different protocols and data formats. The lack of standardization makes data integration difficult, limiting its usability for cross-platform analytics.
- 2. Computational and Storage Constraints** – Processing and storing IoT-generated data require significant infrastructure investments. Startups, particularly those in their early stages, may lack the resources to implement large-scale data processing pipelines.
- 3. Privacy and Security Concerns** – Due to increasing regulatory scrutiny, such as GDPR and California's CCPA, IoT startups must navigate strict data protection laws. This can hinder their ability to leverage collected data, especially when dealing with personally identifiable information (PII).

While these challenges pose barriers to effective data utilization, they also present significant opportunities. Startups that can develop efficient AI-driven analytics, predictive maintenance algorithms, or real-time optimization solutions stand to gain a competitive advantage. Innovations in edge computing, federated learning, and data monetization models may further help unlock the latent potential of IoT-generated data.

## 5.2. Future Directions and Opportunities

One of the most pressing issues in the IoT industry is the lack of standardized protocols and interoperability across devices and platforms. The future of IoT startups will depend on industry-wide collaborations to establish universal communication standards. This will not only improve device compatibility but also enhance security and reliability, fostering wider adoption of IoT solutions. In parallel, the growing demand for real-time data processing has fueled interest in edge computing and AI-powered IoT solutions. Startups that focus on integrating artificial intelligence for predictive analytics, automation, and real-time decision-making will have a competitive advantage. Future research and development should explore how AI-driven IoT can improve efficiency in sectors like healthcare, manufacturing, and smart cities.

As IoT networks expand, cybersecurity threats will continue to rise, making security and data privacy a top concern. Future IoT startups must prioritize robust security frameworks, including end-to-end encryption, blockchain-based authentication, and AI-driven anomaly detection. Addressing privacy concerns through transparent data governance models will be crucial in building consumer and enterprise trust. At the same time, increasing concerns about environmental sustainability present an opportunity for IoT startups to develop energy-efficient solutions and circular economy models. Smart energy management, sustainable manufacturing processes, and the use of biodegradable IoT components can contribute to greener innovations while also aligning with regulatory and corporate sustainability goals.

While investment in IoT startups remains strong, securing funding beyond the initial stages is a challenge. Future research should focus on identifying the factors that contribute to the scalability and long-term success of IoT startups. Exploring alternative funding sources, such as venture debt, government grants, and corporate partnerships, can provide valuable insights for entrepreneurs. Additionally, the IoT sector remains largely concentrated in North America, Europe, and parts of Asia, yet emerging markets in Africa, Latin America, and Southeast Asia present untapped opportunities. Future studies should investigate the barriers to entry in these regions, such as infrastructure limitations, regulatory challenges, and consumer adoption rates, to guide startups in market expansion strategies.

To further enhance the understanding of IoT startups, interviews with industry experts, entrepreneurs, and investors will be conducted in the future. These interviews will provide deeper insights into the challenges, opportunities, and strategic approaches that startups are adopting to succeed in the IoT ecosystem.

The findings of this thesis reinforce the idea that IoT startups are at the forefront of digital transformation, leveraging innovative business models to create value across various industries. However, challenges such as security risks, regulatory complexities, and market fragmentation persist. Moving forward, IoT startups must adapt to technological advancements, evolving regulatory frameworks, and shifting market demands to sustain growth and maximize impact. Future research should continue to explore these dynamics, ensuring that IoT startups remain agile and resilient in an ever-changing digital landscape.

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## Table of Figures

Figure 1: Top 10 IoT Application Areal Among Startups (Last 5 years, sample size 465) .....	30
Figure 2:Yearly Distribution of IoT Startup Foundation (Sample size 1960) .....	31
Figure 3:Yearly Distribution of IoT Startup Foundation (Last 5 years, sample size 465) .....	31
Figure 4: IoT Startups by Market based Business Model Segmentation (Last 5 years, sample size 465) .....	35
Figure 5:Trends in IoT Framework based Business Model Segmentation Over Time	37
Figure 6: Top Countries with the Most IoT Startups (Last 5 years, sample size 465) .	40
Figure 7: Number of IoT Startups by Continent (Last 5 years, sample size 465).....	41
Figure 8: Top 10 Countries with the Most IoT Startups (Last 5 years, sample size 465) .....	42
Figure 9: Heatmap of IoT Startup Funding vs Employee Size (Last 5 years, sample size 465).....	43
Figure 10: Top IoT Application Areas with Most Acquisitions (Last 5 years, sample size 465).....	45
Figure 11: Acquisitions by Continent (Last 5 years, sample size 465).....	45
Figure 12: Total Funding and Number of Startups per Business Model .....	52
Figure 13: Business Model Adoption in Different Regions (Last 5 years, sample size 465).....	57

