

Revisiting IoT Business Model Frameworks in the 5G Era: An Ecosystem Dynamics Perspective

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Abstract

The convergence of 5th Generation Telecommunications (5G) technology and the Internet of Things (IoT) has introduced unprecedented opportunities and complexities, fundamentally reshaping the dynamics of digital ecosystems. However, existing IoT business models, primarily developed for earlier technological landscapes, are increasingly inadequate in addressing the unique demands of the 5G IoT environment. This study critically reviews the current body of research on IoT business models through a narrative literature review, aiming to evaluate their relevance and effectiveness within the evolving 5G ecosystem. The findings reveal significant gaps, particularly in addressing the dynamic, interconnected, and adaptive nature of 5G-enabled ecosystems. Current models fall short in areas such as scalability, stakeholder interdependence, and real-time data monetization, limiting their ability to capture the full potential of 5G IoT networks. This paper highlights the necessity for reimagining business models that are responsive to ecosystem dynamics, fostering value co-creation, adaptability, and collaborative innovation. The insights from this review offer a foundation for developing future-ready business models capable of maneuvering the complexities of the 5G IoT ecosystem, with implications for both academia and industry stakeholders.

Keywords: 5G, business model, ecosystem dynamics, Internet of Things, IoT

1. Introduction

The convergence of Fifth Generation Telecommunications (5G) technology and the Internet of Things (IoT) is fundamentally transforming digital ecosystems, transcending the boundaries of incremental innovation. This synergy leverages 5G's unprecedented features such as ultra-low latency, massive device connectivity, and enhanced data throughput to enable a paradigm shift in how value is created, exchanged, and sustained across industries. Unlike previous technological iterations, 5G amplifies IoT capabilities, necessitating a critical reassessment of business models originally tailored to earlier, less dynamic IoT environments. While substantial research has explored IoT business models (Dijkman et al., 2015; Porter & Heppelmann, 2014), these frameworks often fail to accommodate the complexities introduced by 5G, such as scalability, real-time responsiveness, and multi-stakeholder collaboration. This paper examines the applicability of existing IoT business models within the 5G-driven ecosystem, identifying critical gaps in the literature and offering insights to inform the development of adaptive, future-ready models suited to this transformative IoT landscape.

1.1 Contextual Background on the Evolution of IoT and the Emergence of 5G

The IoT has evolved from a concept of interconnected devices into a sprawling network underpinning smart city, industrial automation, and personalized services (Atzori et al., 2010). However, the advent of 5G introduces a step-change in this evolution, enabling hyper-connectivity and real-time data processing that earlier generations of telecommunications could not support. Existing IoT business models, often rooted in static value propositions and linear value chains, fall short in addressing the dynamic, networked nature of 5G IoT ecosystems. For instance, traditional models struggle to account for the exponential increase in device density, of which 5G is capable of connecting 1 million devices per square kilometer (Escolar et al., 2020), or the need for instantaneous decision-making in latency-sensitive applications like autonomous vehicles or telemedicine. This research gap underscores the urgency of rethinking IoT business frameworks to align with 5G's technical and economic demands. This study aims to critically evaluate the suitability of existing IoT business models within the context of 5G ecosystem dynamics, highlighting deficiencies and proposing pathways for innovation.

1.2 Contribution to Academic Discourse and Industry Relevance

The interplay between 5G and IoT represents a turning point in the trajectory of digital technologies, with profound implications for academia and industry alike. As global ecosystems trend toward hyper-interconnectivity, understanding the nuances of 5G IoT dynamics is essential for driving technological progress, economic vitality, and societal well-being. This study's significance lies in its timely interrogation of an emergent paradigm, bridging theoretical insights with practical imperatives. By dissecting the components and determinants of 5G IoT business models, it offers a lens into the economic and organizational underpinnings of this technology's deployment.

The success of 5G IoT hinges not only on its technical prowess but also on the viability of sustainable, adaptable business models (Teece, 2010). This research addresses this intersection by exploring how ecosystem dynamics, characterized by multi-actor collaboration, resource orchestration, and value co-creation shapes business model innovation. Such insights are invaluable for policymakers crafting regulatory frameworks, industry leaders steering adoption strategies, and entrepreneurs designing scalable solutions. The findings promise to benefit a broad spectrum of stakeholders across the 5G IoT value chain, including service providers, software developers, hardware manufacturers, and solution integrators, equipping them to navigate this rapidly evolving landscape.

1.3 Methodology

To critically examine the relevance of existing IoT business models within the evolving 5G ecosystem, this study employs a narrative literature review approach. This approach enables the identification of conceptual gaps, emerging themes, and patterns within current research on IoT business models, particularly their applicability in addressing the unique demands of the 5G landscape. The selection of literature was guided by relevance to 5G IoT and ecosystem dynamics, as well as citation impact, ensuring that the analysis draws from influential and widely recognized studies.

1.4 Literature Selection Criteria

The literature review on IoT business models leveraged Google Scholar, Scopus, and Web of Science (WoS) for their complementary strengths. Google Scholar's inclusive approach captures a broad range of scholarly works, including journal articles, theses, and unpublished materials (Kulkarni et al., 2009; Martin-Martin et al., 2017), while Scopus and WoS focus on selective, peer-reviewed content with robust citation analysis tools (Baas et al., 2020; Testa, 2009); this multi-database strategy ensured a comprehensive review (Harzing & Alakangas, 2016).

The selection process involved:

- 1) Keyword searches to identify relevant literature.
- 2) Citation tracking using WoS, Scopus, and Google Scholar's "Cited by" feature.
- 3) Inclusion/exclusion criteria based on relevance, methodological rigor, and impact (Ridley, 2012).
- 4) Cross-database verification to ensure completeness (Webster & Watson, 2002).
- 5) The relevance to IoT business model research and citation impact guided final selections, with recent works included to capture emerging trends (Levy & Ellis, 2006).

Searches utilized specific terms like "internet of things," "business model," and "Osterwalder," tied to the widely recognized Business Model Canvas (BMC) framework (Osterwalder & Pigneur, 2010). This approach, aligned with methodologies like PRISMA

(Moher et al., 2009) and systematic reviews (Snyder, 2019; Tranfield et al., 2003), enhanced result relevance by targeting influential frameworks and authors.

Highly cited papers were prioritized as markers of impactful research (Lai, 2020; Bornmann, 2014), though in the nascent field of IoT business models, citation thresholds were contextually adjusted due to limited literature (Guzzetti et al., 2008). Citations, rather than Google Scholar rankings, were favored for assessing influence (Belter, 2016; Fiol et al., 2018).

Using keywords like "IoT business model" and "Business Model Canvas," Google Scholar returned 155 results, with 18 exceeding 50 citations, including seminal works like Osterwalder and Pigneur (2010) and Atzori et al. (2010). Scopus yielded another 17 curated, high-impact papers, such as Westerlund et al. (2014), while WoS returned zero, suggesting limited coverage in high-impact journals. The disparity in results reflects the emerging nature of IoT business model research. Google Scholar's broad scope contrasts with the selective indexing of Scopus and WoS, indicating a field still gaining recognition (Atzori et al., 2010). The scarcity of highly cited papers may stem from its novelty or niche focus, a pattern seen in other emerging fields (Chesbrough & Rosenbloom, 2002). To investigate the selection process of relevant literature, a PRISMA flowchart (Figure 1) illustrates the systematic identification, screening, eligibility assessment, and inclusion of studies for the review of IoT business models.

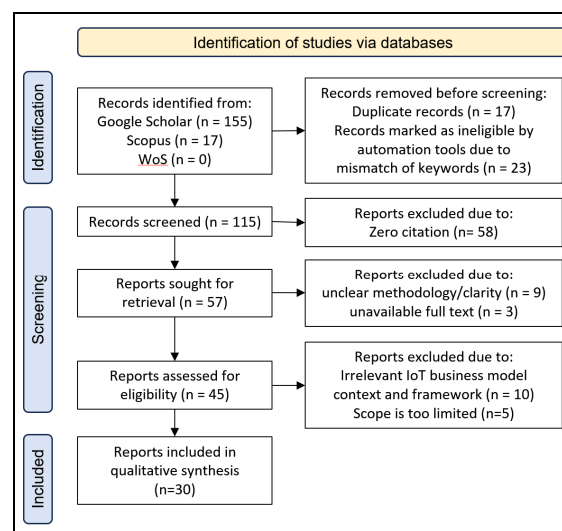


Figure 1. PRISMA flowchart for literature selection in IoT business model review

Diagram adapted from Haddaway et al, (2022).

2. Literature Review

The IoT has become a key area of interest in research due to its impact on how businesses create value, deliver services, and stay connected. This literature review focuses on how IoT

and business models work together, summarizing research to understand how they have developed and what themes are most important. By looking at what has already been studied, this review aims to explain how IoT changes business models and point out areas where more research is needed.

2.1 Narrative Literature Review

This study adopts a narrative literature review (NLR) to explore 5G IoT business models globally, using Malaysia's telecommunications industry as a contextual example. The NLR's qualitative, flexible approach suits the complexity of IoT ecosystems, offering in-depth theoretical insights (Creswell & Creswell, 2017), contextual understanding (Merriam & Tisdell, 2015), and integration of diverse sources (Booth et al., 2016). It synthesizes global perspectives (Hart, 1998) and aligns with objectives to build a broadly applicable framework, identifying gaps and opportunities (Bryman et al., 2022; Ridley, 2012). While Malaysia illustrates local influences, the review transcends regional limits, advancing universal knowledge on 5G IoT business models.

Given the reviewer's extensive experience of over 20 years in the IoT business and industry, a narrative literature review is particularly suitable, as it leverages their experiential knowledge to provide a critical interpretation of the literature, enhancing the synthesis and contextualization of findings (Dixon-Woods et al., 2006). The interdisciplinary and rapidly evolving nature of the 5G IoT field also makes NLR a highly suitable research methodology. NLRs excel at synthesizing fragmented knowledge across diverse domains, such as telecommunications, data security, and smart applications, which is essential for a multifaceted field like 5G IoT (Snyder, 2019). Additionally, they are effective in consolidating current findings and proposing future research directions, making them ideal for dynamic areas with continuous advancements (Greenhalgh et al., 2018). The versatility of NLRs further supports their applicability, providing a comprehensive and adaptable overview of ongoing developments in 5G IoT (Grant & Booth, 2009).

2.2 The Internet of Things (IoT)

The IoT is a transformative technology that has gained significant traction in recent years. It can be defined as a global ecosystem of information and communication technologies aimed at connecting any type of object at any time and in any place to each other and to the Internet (Villamil et al., 2020). This paradigm involves the connection and exchange of information between millions of smart devices, enabling the communication and exchange of data between various physical devices via the Internet (Omran et al., 2021). IoT encompasses a network of physical objects embedded with sensors, software, and other technologies to communicate and exchange data with other devices and systems over the Internet (Al-Nasser et al., 2025).

From a technical perspective, IoT relies on various interconnected technologies for

exchanging information between devices that can be identified and monitored over the Internet (Himmat et al., 2022). The IoT technology has provided strong technical support for the transformation of industries such as logistics, smart manufacturing, smart homes, and smart cities (Yu & Mai, 2020). It enables the integration of modern technologies like cyber-physical systems, cloud computing, and big data, contributing to the advancement of Industry 4.0 (Kumar et al., 2020).

IoT devices are equipped with various sensors that collect data from their surroundings. These sensors can measure things like speed, temperature, g-force, and more. Connectivity options include Bluetooth, Wi-Fi, cellular networks such as 5G, and low-power wide-area networks (LPWAN), allowing devices to transmit data to centralized servers or other devices (Atzori et al., 2010). Once data is gathered from IoT devices, it must undergo processing and analysis to extract valuable insights. This process involves methods such as data aggregation, and advanced analytical techniques, including machine learning and artificial intelligence (AI). These approaches help identify patterns, trends, and anomalies within the data, facilitating informed decision-making. Due to the sensitive nature of IoT data, maintaining security and privacy is crucial. This requires encrypting data both in transit and at rest, implementing authentication mechanisms to verify the identities of devices and users, and regularly updating security measures to mitigate vulnerabilities and cyber threats.

IoT enables businesses to streamline operations and increase efficiency by automating tasks, monitoring equipment performance in real-time, and optimizing resource usage. For example, in manufacturing, IoT sensors' data can be analyzed to predict equipment failures, minimizing downtime and reducing maintenance costs. Furthermore, it enables businesses to create new products and services. By leveraging IoT data, companies can offer value-added services such as predictive maintenance, remote monitoring, and personalized experiences (Manyika et al., 2015). This can lead to additional revenue streams and enhanced customer satisfaction.

Businesses are increasingly leveraging IoT to enhance operations and services. IoT is the core foundation of smart cities, national defense, and intelligent manufacturing industries (Kubler et al., 2015). The application of IoT extends to various sectors such as healthcare, sports fitness management, and supply chain operations, offering immense potential for innovation and efficiency (Dutta et al., 2020; Qatawneh et al., 2020; Tang & Wang, 2020). Moreover, IoT plays a crucial role in optimizing product design, enhancing enterprise privacy resource management, and improving service delivery in sectors like libraries and healthcare (Bo & Huang, 2022; Eiriemiokhale & James, 2023; Xu et al., 2022).

The wealth of data generated by IoT devices empowers businesses to make data-driven decisions. By analyzing IoT data, businesses can gather insight such as customer behavior, market trends, and operational performance, enabling them to optimize processes, develop targeted marketing strategies, and identify new business opportunities. However, the adoption growth of IoT also brings forth challenges. Security and privacy concerns are paramount due to the increasing number of connected devices, posing novel challenges that need to be

addressed (Shirish & Jyoti, 2022). Additionally, the integration of blockchain technology with IoT is being explored to enhance security and privacy in supply chain operations and various IoT applications (Dutta et al., 2020). Despite the potential benefits, implementing IoT solutions comes with challenges such as interoperability issues, data privacy concerns, and scalability concerns. Businesses must carefully consider these factors and develop strategies to address them effectively.

The IoT market comprises various components, including revenue, revenue growth, IoT investment, and a ranking of leading companies along with their total revenues. It encompasses revenue streams derived exclusively from IoT-related activities, such as hardware sales (e.g., sensors, chips, and other devices), platforms (e.g., IoT platforms, security software, and other applications), connectivity solutions (e.g., cellular, LoRa, SigFox, and similar technologies), and services (e.g., system integration and maintenance). For instance, in the case of a smart security camera, only the portion that enables connectivity and intelligence is considered pure IoT revenue, excluding the total product cost. The reported market revenues account for expenditures from consumers (B2C), businesses (B2B), and government entities (B2G). Revenue attribution is based on the country where the expenditure occurs. For example, a comprehensive IoT solution might involve hardware sourced from a local vendor, application software hosted on a cloud server in another country, and connectivity services provided by both domestic and international operators.

In summary, the IoT is a multifaceted technology that offers immense opportunities for technical innovation and business transformation. By connecting devices and enabling data exchange over the Internet, IoT is revolutionizing industries and driving advancements in various sectors. However, addressing security and privacy challenges is crucial to realizing the full potential of IoT in a connected world.

2.3 Business Model

A business model is a strategic framework that defines how a company creates, delivers, and captures value. It is a comprehensive plan that outlines the core aspects of a business, including its value proposition, customer segments, channels, customer relationships, key resources, partners, and activities; revenue streams, and costing structure (Osterwalder & Pigneur, 2010). This framework helps businesses understand their market position, identify opportunities for growth, and make informed decisions. The concept of a business model has been a pivotal aspect of entrepreneurship and strategic management, serving as the blueprint for how an organization creates, delivers, and captures value. This section delves into the origins, evolution, and applications of business models, drawing upon academic references to provide a comprehensive understanding. It emerged in the 1990s, particularly with the rise of the internet and e-commerce. Timmers (1998) was among the early scholars to discuss the idea in the context of internet businesses. A widely accepted definition by Osterwalder (2005) describes a business model as a conceptual tool containing a set of elements and their relationships, which allows expressing a company's logic of earning money.

The term "business model" gained prominence in the late 20th century, particularly during the dot-com era, when internet-based businesses disrupted traditional industries. However, the concept itself dates back much earlier, with roots in various economic and management theories. Schumpeter's (1943) theory of creative destruction highlighted the importance of innovation in creating new business models, while Porter's (1980) competitive strategy framework emphasized the need for differentiation and cost leadership strategies. Drucker (1994) emphasized the importance of understanding customer needs and delivering value; and Collins and Porras (1994) introduced the concept of "Big Hairy Audacious Goals" (BHAGs) as a driving force for business model innovation.

A key aspect of a business model is its value proposition, which defines the unique benefits and solutions the company offers to its customers (Johnson et al., 2008). The customer segments component focuses on identifying and understanding the target audience, while channels describe the methods used to reach and deliver value to these customers. Revenue streams outline how the business earns money, and the cost structure details the expenses involved in operating the business.

Understanding and innovating business models are crucial for companies to remain competitive and adapt to changing market conditions. Successful business models are those that align closely with customer needs, leverage key resources and partnerships effectively, and ensure sustainable profitability (Chesbrough & Rosenbloom, 2002). As businesses grappled with the complexities of the digital age, the concept of business models gained greater significance, leading to the development of various frameworks and theories. Developed by Osterwalder and Pigneur (2010), the Business Model Canvas provides a visual tool for describing, analyzing, and designing business models. Disruptive Innovation Theory introduced by Christensen (2013) examines how new entrants can disrupt established industries by introducing innovative business models. Proposed by Kim and Mauborgne (2004), this framework focuses on creating uncontested market spaces by developing unique value propositions and business models.

In the recent years, the concept of a business model has evolved significantly, especially with the rise of digital and networked technologies. Traditional business models, such as product-based or service-based models, have expanded to include subscription models, platform-based models, and freemium models, among others (Teece, 2010). Each model offers different mechanisms for revenue generation and customer engagement. Business models have become increasingly relevant in today's dynamic business landscape, serving as a guiding framework for organizations across various industries. In the area of digital transformation, the rise of digital technologies has necessitated the development of new business models, such as platform-based models (e.g., Uber, Airbnb) and subscription-based models (e.g., Netflix, Spotify) (Parker et al., 2016). Business models have been leveraged to address sustainability challenges and create social impact, leading to the emergence of concepts like social entrepreneurship and shared value creation (Porter & Kramer, 2011). Innovative business models can disrupt industries, creating new revenue streams and enabling

companies to gain a competitive advantage (Zott et al., 2011).

2.4 IoT Business Model

The most relevant references were reviewed in identifying the IoT business model and its elements, this review synthesizes insights from these influential publications in the field of IoT business models, providing a comprehensive overview of the current state of research and identifying key trends and challenges.

The table in Appendix A represents a comprehensive review of business model research, tracking the evolution of academic studies from 2002 to 2020. It highlights key business model elements and digital transformation characteristics across various research efforts. The studies primarily focus on understanding how businesses create value, adapt to technological changes, and develop innovative models. Most research concentrated on core elements like value propositions and key resources, with emerging interest in digital transformation and ecosystem dynamics. Geographically, the studies span multiple countries, demonstrating the global relevance of business model innovation research.

Existing literatures extensively explores various aspects of business models and ecosystem partnerships in the context of IoT. However, with the unique capabilities and challenges presented by 5G, there is a growing need to revisit existing business models and assess their suitability for a 5G-enabled IoT environment. This literature review explores the similarities and differences among various studies on business models in IoT. It further identifies the gaps in current research, emphasizing why these models may not be fully applicable to 5G IoT business contexts.

Many studies, such as Westerlund et al. (2014) and Gassmann et al. (2019), focus on defining clear value propositions that cater to specific customer needs in IoT environments. These studies emphasize the importance of offering unique value through IoT-enabled products and services, such as enhanced connectivity, remote monitoring, and real-time data analytics.

A broad review of the literature reveals a diverse range of perspectives on business models for IoT. Westerlund et al. (2014) provide a comprehensive framework for designing business models tailored to the IoT context, emphasizing value creation, delivery, and capture mechanisms within complex ecosystems. This study underlines the importance of adaptability and partnerships among multiple stakeholders, such as device manufacturers, service providers, and end-users, to foster innovation and sustain competitive advantage. Similarly, Chesbrough and Rosenbloom (2002) highlight the critical role of business models in capturing value from technological innovations. Their work, while not explicitly focused on IoT, provides foundational insights into how firms can leverage business models to transform new technologies into economic value.

The literature consistently highlights the role of customer relationships and channels in delivering IoT solutions. For example, Dijkman et al. (2015) and Chan (2016) discuss the importance of maintaining strong customer relationships through personalized services and

using various channels, including digital platforms and direct customer interaction, to distribute IoT products and services.

Several studies, including Bilgeri et al. (2015) and Endres et al. (2019), identify key activities like software development, data management, and hardware maintenance as critical to the success of IoT business models. Additionally, the importance of key resources, such as IoT platforms, data analytics tools, and skilled personnel, is widely acknowledged.

There are noticeable similarities across these studies in terms of recognizing the necessity of robust partnerships and dynamic ecosystems for thriving in a rapidly evolving technological landscape. For example, Palattella et al. (2016) discuss the essential enablers and architecture necessary for IoT in the 5G era, pointing out that 5G's capabilities significantly enhance IoT applications by offering improved connectivity, latency, and bandwidth. However, while these studies acknowledge the importance of ecosystem dynamics and partnerships, they do not delve deeply into the specific dynamics and structural requirements unique to 5G IoT environments. The studies predominantly focused on and originating from the Western geographical regions. A significant portion of the research and case studies on IoT business models appears to be based on USA and European countries, especially the United Kingdom, Germany, and the Nordic nations.

Despite these commonalities, there are significant differences in how these studies approach the subject. While some research, like that of the St. Gallen Business Model Navigator (Gassmann et al., 2019), focuses on categorizing and mapping various business models applicable to IoT, others take a more technological or network-centric approach. For instance, Bilgeri et al. (2015) propose a conceptual tool, the IoT Business Model Builder, to assist companies in identifying and implementing IoT business models. This tool, while useful, does not specifically address the unique challenges posed by the 5G network, such as ultra-reliable low latency communication (URLLC) and massive machine-type communication (mMTC).

Some studies, such as Bucherer and Uckelmann (2011) and Lindgren and Rasmussen (2013), place a strong emphasis on key partnerships within the IoT ecosystem. These studies argue that strategic alliances with technology providers, data aggregators, and service integrators are crucial for developing comprehensive IoT solutions. Conversely, other studies like Ju et al. (2016) focus less on partnerships and more on internal capabilities and resource management.

Although there are ecosystem and partnership considerations in current studies, they do not adequately address the 5G IoT ecosystem dynamics requirements. The 5G IoT environment introduces several distinct challenges and opportunities that differ from traditional IoT models, particularly regarding network slicing, edge computing, and the integration of AI. These new dynamics necessitate an evolved understanding of partnerships and business models that can accommodate the greater complexity, data volume, and the need for near-instantaneous data processing and response times (Palattella et al., 2016).

There is also variability in how different studies approach revenue streams and cost structures.

For instance, Tesch et al. (2017) highlight innovative revenue models such as subscription services and data monetization, while Lee and Lee (2015) focus on traditional revenue streams like product sales and licensing. Cost structures also vary, with some studies emphasizing cost optimization through economies of scale (Muller et al., 2018) and others focusing on high upfront costs associated with IoT infrastructure development (Oughton & Frias, 2018).

A significant gap in the literature is evident when comparing traditional IoT frameworks with the demands of a 5G-enabled IoT ecosystem, particularly regarding the insufficient focus on ecosystem dynamics within business models. Existing studies predominantly address technological and operational aspects, leaving critical elements of ecosystem interactions, value co-creation, and stakeholder interdependencies in the 5G IoT context underexplored.

Current studies also fail to capture the nuanced requirements of 5G IoT, such as enhanced interoperability between heterogeneous devices and systems, the requirement for real-time data analytics, and more sophisticated cybersecurity measures. Addressing this gap is crucial for several reasons. Firstly, businesses and stakeholders need to understand how to effectively monetize 5G IoT applications and services. Secondly, with the increasing convergence of various technologies within the 5G IoT ecosystem, there is a need for more collaborative and integrated business models that can support multi-stakeholder environments.

In conclusion, while existing literature provides a strong foundation on business models and ecosystems in the context of IoT, it does not fully encompass the unique dynamics of the 5G IoT environment. This gap needs to be addressed to enable the development of business models that are not only sustainable but also capable of leveraging the full potential of 5G technologies. Future research should focus on creating frameworks that consider the high-speed, low-latency, and high-density characteristics of 5G IoT, facilitating more effective partnerships and ecosystem dynamics tailored to this new technological landscape.

2.5 Business Model Evolution in IoT

The advent of the IoT has significantly impacted business model conceptualization and design. Based on analysis of 30 key literatures in the IoT business model space in the previous section, by examining how researchers have adapted existing frameworks and proposed new ones to capture the unique characteristics of IoT-driven businesses.

A prominent trend observed across the literature is the adaptation of the BMC for IoT contexts. Fleisch et al. (2015), Dijkman et al. (2015), and Hsu and Lin (2016) all utilized the standard nine blocks of the BMC as a foundation. However, recognizing the need for IoT-specific considerations, researchers like Lee and Lee (2015), Gierej (2017), and Endres et al. (2019) proposed modifications to the BMC to better reflect the technological and ecosystem aspects of IoT business models.

While the BMC remains influential, many researchers have gravitated towards more value-centric frameworks. Westerlund et al. (2014) introduced a model focusing on four key

elements: value proposition, value creation, value capture, and value network. This approach has been echoed and expanded upon by several other studies. Ju et al. (2016), Muller et al. (2018), and Leminen et al. (2018) all adopted similar value-centric frameworks, with the addition of "value delivery" as a distinct element. This recurring theme underscores the importance of value creation and delivery in IoT business models, reflecting the complex ecosystem of stakeholders and the data-driven nature of IoT services.

The concept of value networks or ecosystems has gained prominence in IoT business model research. Evans et al. (2017) and Metallo et al. (2018) incorporated the value network as a crucial component in their frameworks, recognizing the interconnected nature of IoT systems and the importance of partnerships in creating and delivering value. This ecosystem perspective is further emphasized by Pirola et al. (2020), who explicitly included "ecosystem" as a key element in their framework.

Some researchers have proposed more specialized frameworks to capture the unique aspects of IoT business models. Turber et al. (2014) introduced a model based on three dimensions: Who (stakeholders), Where (sources of value creation), and Why (benefits). This approach offers a different perspective on value creation in IoT ecosystems, focusing on the roles and motivations of various stakeholders. The financial aspects of IoT business models have also received attention. Niyato et al. (2016) highlighted the importance of revenue models and cost structures in their framework, while Tesch et al. (2017) introduced "value finance" as a distinct element. These contributions reflect the need to consider new revenue streams and cost structures that emerge in IoT-enabled business models. Paschou et al. (2020) took a more granular approach, breaking down their framework into specific components such as key resources, key activities, partner network, customer segments, and revenue streams. This detailed perspective allows for a more nuanced understanding of the various elements that contribute to IoT business models. More recent research has begun to explore the role of platforms in IoT business models. Schreieck et al. (2017) introduced "platform governance" as a key element, recognizing the growing importance of IoT platforms in facilitating value creation and capture across ecosystems.

The analysis of the literatures reveals a clear evolution in IoT business model conceptualization. While early works often adapted existing frameworks like the BMC, later studies have increasingly focused on value-centric models that emphasize ecosystem dynamics, stakeholder relationships, and platform-based strategies. Common themes that emerge across the literature include:

- 1) The central role of value creation, delivery, and capture in IoT business models;
- 2) The importance of ecosystem considerations and partner networks;
- 3) The need for IoT-specific adaptations to traditional business model frameworks;
- 4) The growing recognition of platforms and their governance in IoT contexts;
- 5) The exploration of new revenue models and cost structures specific to IoT.

By tracking the evolution of business model thinking in IoT, from adaptations of general models to the development of IoT-specific frameworks, this categorization provides valuable insights into the maturation of the field (Leminen et al., 2018). For businesses, this division offers a clear starting point for selecting an appropriate model based on their level of IoT integration and specific industry needs (Gassmann et al., 2019).

In conclusion, the analysis of the key literature demonstrates a shift from traditional business model approaches to more specialized, value-centric models that emphasize ecosystem dynamics, stakeholder relationships, and platform-based strategies in the IoT context. While there is no one-size-fits-all framework, the recurring themes identified provide valuable insights for researchers and practitioners seeking to understand and develop IoT business models. Future research could benefit from further refinement of these frameworks, potentially incorporating emerging aspects such as data monetization, privacy considerations, and the impact of complementary technologies like AI and edge computing on IoT business models.

3. Results

Based on the articles reviewed, five key themes have been identified to emerge across the works: Value Creation and Capture, Ecosystem and Platform Approaches, Technological Infrastructure, Customer-Centric Approaches, and Sustainability. These themes provide a lens through which to assess the current state of IoT business models and their readiness for 5G environments.

The value creation and capture theme focus on how IoT enables organizations to generate and monetize value in innovative ways.

- **Data Monetization:** Several articles highlight the role of data as a core asset in IoT business models. For instance, Li and Xu (2013) explore how IoT-generated data can be leveraged for insights or sold as a service, while Ju et al. (2016) emphasize data analytics as a revenue driver. These works suggest that businesses can shift from traditional product sales to data-driven offerings.
- **Service-Oriented Models:** Bucherer and Uckelmann (2011), an early IoT-specific study, introduces the transition from selling physical products to providing services such as predictive maintenance or pay-per-use models. Similarly, Dijkman et al. (2015) offer a taxonomy of IoT business models, including subscription or outcome-based approaches.

IoT business models often rely on collaboration and interconnected systems, making ecosystems and platforms a recurring theme. Westerlund et al. (2014), in their work on designing IoT business models, stress the importance of ecosystem thinking, where multiple stakeholders collaborate to deliver value. Bilgeri et al. (2015) extend this to specific contexts, such as automotive IoT ecosystems. Hodapp et al. (2019) and Turber et al. (2014) explore platform-based models, where IoT enables network effects and multi-sided markets. Lindgren and Rasmussen (2013) provide frameworks for ecosystem-driven innovation, emphasizing

scalability and interdependence.

The technical foundations of IoT, such as connectivity and analytics, are critical to its business models. Palattella et al. (2016) discuss connectivity standards (e.g., 4G, LPWAN), which underpin IoT deployments. Chiang and Zhang (2016) address technical challenges like network reliability or latency, though possibly in a pre-5G context. Fleisch et al. (2015) identify business model patterns enabled by data analytics, such as remote monitoring, while Shafique et al. (2020) focus on security and privacy challenges in IoT, potentially mentioning 5G.

IoT business models increasingly prioritize tailored, outcome-focused services. Keiningham et al. (2020) examine how IoT enhances customer experiences through personalized offerings, leveraging real-time data. Lee and Lee (2015) explore applications like smart homes, where customer needs drive service design. Tesch et al. (2017) discuss innovation processes leading to outcome-based models, where customers pay for results (e.g., uptime) rather than products. Chan (2016) presents a case study, illustrate it in a specific industry like healthcare.

Though less prominent, sustainability emerges as a theme in some works. Boons and Lüdeke-Freund (2013) link IoT to sustainable business models, such as energy efficiency or circular economy practices. Lehoux et al. (2014), focused on healthcare, explore IoT's role in resource optimization.

Foundational papers like Chesbrough and Rosenbloom (2002) and Amit and Zott (2010) provide general business model innovation concepts, which later IoT-specific studies build upon. Gassmann et al. (2019) offer patterns applicable to IoT, while recent works like Endres et al. (2019), Leminen et al. (2018), and Metallo et al. (2018) address evolving challenges or future directions. Industry-specific studies (Gierej, 2017; Muller et al., 2018) and 5G-related papers (Oughton & Frias, 2018; Rao & Prasad, 2018) add contextual depth of industry specific use cases such as Industry 4.0.

4. Discussion

The ecosystem dynamics of 5G IoT involve a complex interplay of technologies, stakeholders, and regulatory frameworks that collectively shape the development and deployment of IoT applications. The advent of 5G technology is a significant enabler for IoT, primarily due to its enhanced capabilities such as higher data rates, ultra-low latency, and massive device connectivity. These features make 5G particularly suitable for supporting the diverse and demanding requirements of IoT applications across various sectors, including healthcare, manufacturing, transportation, and smart cities (Shafi et al., 2017).

The 5G IoT ecosystem comprises several key components: network infrastructure providers, device manufacturers, platform providers, application developers, and end-users. Network infrastructure providers, such as communication service providers (CSPs), are responsible for deploying and maintaining the 5G networks that facilitate IoT communication. Device manufacturers produce the hardware required for IoT devices, including sensors and

communication modules. Platform providers offer the software infrastructure, such as cloud computing services and data analytics platforms, necessary for managing IoT devices and processing the huge amounts of data generated by them. Application developers design and implement IoT solutions tailored to specific industry needs, while end-users ranging from businesses to consumers utilize these solutions to achieve their objectives, such as improved operational efficiency or enhanced customer experiences.

The dynamics of the 5G IoT ecosystem are characterized by significant interdependencies and collaboration among its components. For instance, network infrastructure providers and device manufacturers must work closely to ensure that IoT devices are compatible with 5G standards and can operate efficiently on the network. Similarly, platform providers and application developers collaborate to create integrated solutions that leverage the capabilities of 5G networks, such as edge computing, to provide real-time analytics and decision-making capabilities (C. Zhang et al., 2019). These interdependencies require a high level of coordination and standardization across the ecosystem, facilitated by industry bodies such as the 3rd Generation Partnership Project (3GPP) and the International Telecommunication Union (ITU).

To investigate the interplay of ecosystem dynamics within the 5G IoT context, the application of ecosystem strategy theory, as proposed by Adner (2017), provides a robust theoretical lens to understand the collaborative and competitive interactions among CSPs. Adner's framework emphasizes the importance of alignment among ecosystem partners to deliver value propositions, highlighting the need for CSPs to strategically position themselves within the 5G IoT ecosystem to mitigate risks and leverage opportunities. For instance, CSPs must align their network infrastructure advancements with the demands of IoT applications to ensure seamless integration and performance, fostering value co-creation with platform providers and application developers. Additionally, integrating platform governance frameworks, as articulated by Tiwana (2013), enhances the understanding of how CSPs can govern their interactions within the ecosystem. Tiwana's framework underscores the role of governance mechanisms, such as standardization and modular architectures, in balancing control and flexibility to support innovation while ensuring compatibility across diverse IoT devices and applications. By embedding these theoretical perspectives, the analysis of the 5G IoT ecosystem reveals how CSPs can navigate interdependencies, optimize resource allocation, and drive sustainable business models, thereby addressing the limitations of non-5G IoT networks and enhancing competitive advantage in dynamic market environments.

The non-5G IoT ecosystem has been adequate for many business applications, but its limitations are increasingly evident as companies look to leverage IoT for more complex and demanding use cases. From a business perspective, the current non-5G IoT landscape is characterized by several key challenges; businesses relying on non-5G IoT networks often face operational inefficiencies due to bandwidth constraints and higher latency. For instance, in manufacturing, the inability to achieve real-time monitoring and control can lead to delays,

increased downtime, and reduced productivity. The scalability of non-5G networks is limited, which restricts businesses from expanding their IoT deployments. Companies looking to scale up operations or diversify their IoT applications find it challenging to do so without facing significant performance bottlenecks. Due to inefficiencies in network performance, businesses may incur higher costs related to network management, device maintenance, and energy consumption. Non-5G networks often require more infrastructure and energy to support large-scale IoT deployments, leading to increased operational expenses.

Many new business models, such as those based on real-time data analytics, predictive maintenance, and automation, require low-latency, high-reliability networks. Non-5G IoT networks struggle to support these models, limiting innovation and competitiveness for businesses. The less robust security features of non-5G IoT ecosystems expose businesses to greater risks of data breaches, cyberattacks, and non-compliance with data protection regulations. This not only threatens operational continuity but also damages customer trust and brand reputation.

4.1 Limitation of Current IoT Business Models for 5G

Current IoT business models do not sufficiently account for the complex interactions and interdependencies amplified by 5G within the IoT ecosystem. These include multi-stakeholder collaborations, equitable data sharing, and the need for rapid adaptation to evolving technological standards. Unlike previous connectivity generations, 5G enables real-time, mission-critical applications such as autonomous vehicles and remote surgery that require business models to dynamically adjust to new roles, partnerships, and value chains. However, the reviewed articles, spanning foundational works like Chesbrough and Rosenbloom (2002) to more recent studies like Shafique et al. (2020) are often rooted in pre-5G contexts, limiting their relevance to these emerging demands.

4.2 Infrastructure and Technical Capabilities: A Disconnect

Traditional IoT business models, such as those proposed by Westerlund et al. (2014) and Ju et al. (2016), focus primarily on value creation from service providers and end-users, often overlooking the critical role of network infrastructure providers. The deployment of 5G necessitates massive investments in small cells, spectrum acquisition, and other resources, introducing novel value propositions such as network-as-a-service (Oughton & Frias, 2018). Moreover, 5G's network slicing capability allows for the creation of customized virtual networks tailored to specific IoT use cases, opening up monetization opportunities like on-demand services (H. Zhang et al., 2017). These aspects remain largely unaddressed in the existing literature.

The integration of edge computing in 5G IoT further enhances distributed data processing, significantly reducing latency for time-sensitive use cases such as autonomous vehicles, remote surgery, and industrial automation (Leminen et al., 2018; Muller et al., 2018). However, the business implications of these ultra-low latency and edge-based value creation mechanisms are conspicuously absent from current frameworks. Additionally, 5G's mMTC

capability supports unprecedented device densities with potentially millions of devices per square kilometer, presenting both scalability challenges and opportunities that models like those of Evans et al. (2017) and Metallo et al. (2018) fail to capture comprehensively.

Examining the timeline of the literature reveals further gaps. Early works such as Bucherer and Uckelmann (2011), Westerlund et al. (2014), and Dijkman et al. (2015) were developed under assumptions of 4G or earlier connectivity standards, as 5G did not become commercially viable until around 2019. For example, Dijkman et al. (2015) provide a robust IoT business model framework, but without addressing 5G's ultra-low latency or massive scalability, it falls short of supporting real-time or large-scale IoT use cases. Similarly, Palattella et al. (2016) and Chiang and Zhang (2016) focus on connectivity and technical challenges, but their pre-5G context limits their applicability to 5G-enabled business models. Fleisch et al. (2015) discuss patterns like remote monitoring, which 5G could enhance with real-time capabilities, yet the paper likely does not explore this shift due to its earlier publication date.

Even more recent papers may not fully bridge this gap. For instance, Hodapp et al. (2019) and Endres et al. (2019) discuss platform models or adoption challenges, but unless explicitly tied to 5G's unique features, they miss how massive connectivity alters ecosystem dynamics. Shafique et al. (2020) address 5G IoT security concerns but not extending their analysis to the broader business model implications. Meanwhile, articles explicitly mentioning 5G, such as Oughton and Frias (2018) with its focus on 5G infrastructure economics; and Rao and Prasad (2018) exploring 5G IoT applications, tend to emphasize technical or cost aspects rather than offering a holistic view of how business models must evolve. These siloed approach underscores a critical disconnect in the literature.

4.3 Data Management and Analytics: Unexplored Opportunities

Data serves as a foundational element in IoT value creation, and although Niyato et al. (2016) acknowledge its significance, their work overlooks 5G's profound capacity to handle and analyze massive, real-time data flows. This advancement paves the way for innovative data monetization approaches, including real-time analytics that support dynamic pricing or predictive maintenance—areas that remain largely untapped in prevailing models. Moreover, 5G's superior data handling fosters AI-integrated applications, like predictive maintenance in manufacturing or instantaneous optimizations in urban infrastructure. Yet, frameworks such as those proposed by Paschou et al. (2020) fall short in weaving these technologies into the fabric of value creation, thereby limiting insights into how 5G IoT elevates data to a core strategic resource spanning various sectors.

To illustrate 5G IoT in industrial innovation, Bosch's 5G-equipped pilot plant in Stuttgart links hundreds of sensors and control systems into digital twins and dashboards. Real-time data flow via 5G with Time-Sensitive Networking enables live condition monitoring, AGV coordination, and anomaly detection enabling proactive production adjustments without onsite intervention. This showcases how CSP-enabled mMTC infrastructure supports

resilience and responsiveness in Industry 4.0 ecosystems (Dixit & Ozsevim, 2025; Frazer, 2025)

In addition, 5G's high-speed transmission and edge computing features facilitate immediate data services, for instance, enabling dynamic pricing in fleets of autonomous vehicles or rapid anomaly identification in energy grids. Traditional data monetization frameworks, such as the one outlined by Li and Xu (2013) in their exploration of IoT business models grounded in Multi-Objective Programming (MOP), do not capitalize on these opportunities fully. Li and Xu's model emphasize optimizing multiple objectives such as cost efficiency, resource allocation, and stakeholder value within IoT ecosystems, but it operates under assumptions tied to pre-5G constraints, where data processing occurs in slower, batch-oriented cycles rather than the continuous, low-latency streams that 5G introduces. Consequently, 5G alters the applicability of their MOP-based approach by necessitating adaptations for real-time decision-making; for example, CSPs could extend Li and Xu's optimization parameters to incorporate edge-enabled analytics, transforming static monetization into adaptive strategies that respond to instantaneous data inputs and enhance revenue streams in dynamic environments. The massive mMTC aspect of 5G accommodates connections for millions of devices, producing data quantities that surpass the scalability envisioned in conventional subscription or platform paradigms (Hodapp et al., 2019), which often presume more modest deployments. Likewise, 5G's URLLC support applications with rigorous service guarantees, including remote medical procedures or automated factory operations, which models centered on customer experiences (Keiningham et al., 2020) have yet to embrace, given their orientation toward less urgent scenarios.

4.4 Ecosystem and Partnership Dynamics: A Complex Web

Ecosystem dynamics are central to IoT success, and while Leminen et al. (2018) discuss ecosystems, they do not capture the intricate value co-creation and revenue-sharing mechanisms required among diverse 5G stakeholders, including network operators, cloud providers, device manufacturers, and vertical industry partners. The convergence of industries facilitated by 5G IoT such as healthcare, transportation, and energy in smart cities creates new partnership opportunities and value propositions that models like Turber et al. (2014) overlook, leaving a critical aspect of the 5G IoT landscape unaddressed.

Moreover, 5G amplifies the complexity of the IoT ecosystem by relying on unprecedented cooperation among telecom operators, device makers, and service providers. Current business models lack governance structures to manage these multi-stakeholder collaborations effectively. With 5G generating massive data flows across these partnerships, there is a pressing need for mechanisms to fairly share and profit from this data, a need that the existing literature consistently overlooks. The fast-evolving standards and technologies of 5G, such as ongoing enhancements to network slicing and edge computing, further demand adaptable business models capable of keeping pace with innovation. This flexibility is another dimension that current frameworks fail to explore, leaving businesses ill-prepared for the dynamic 5G ecosystem environment.

4.5 Financial and Operational Considerations: Unanswered Questions

The financial and operational demands of 5G IoT are substantial, yet current business models do not adequately address them. The significant capital expenditure required for 5G deployment—including investments in infrastructure, spectrum, and ongoing maintenance is well-documented by Oughton and Frias (2018), but frameworks like Westerlund et al. (2014) do not consider these costs, raising unanswered questions about the viability of IoT services and strategies for recouping investments. The rapid pace of 5G evolution also necessitates continuous research and development to stay competitive, a factor ignored by studies such as Palattella et al. (2016), which risks underestimating the resources needed to sustain 5G IoT operations.

Vodafone's 2022 lab trial with Ericsson in the UK exemplifies this tension: the operator configured an on-demand 5G slice in under 30 minutes, delivering 260 Mbps download and 12.4 ms latency tailored for virtual reality applications. While such slicing enables rapid, customized CMS deployment, it also raises questions about the sustainability of provisioning ultra-reliable performance at scale and its implications for CSP cost structures (Ericsson and Vodafone Create UK's First 5G Network Slice, 2022; "UK First," 2022)

Operational resilience is another concern, the absence of robust business continuity plans for disruptions such as network outages or cybersecurity threats, as highlighted by Khan et al. (2019) and Radanliev et al. (2020), undermines the reliability of current models in the face of 5G's complexity. For example, the increased attack surface introduced by millions of connected devices and edge nodes in 5G IoT heightens vulnerability to cyberattacks, yet existing frameworks offer little guidance on mitigating these risks or ensuring operational continuity.

4.6 Regulatory and Sustainability Concerns: Overlooked Challenges

The pervasive nature of 5G IoT introduces a host of regulatory and sustainability challenges that current business models fail to address. Evolving regulations around data privacy, spectrum allocation, and cybersecurity driven by the heightened security risks of 5G, such as distributed denial-of-service attacks require proactive strategies, yet existing frameworks provide little insight into navigating these constraints. The energy-intensive demands of 5G IoT applications, from dense small cell networks to edge computing infrastructure, also raise sustainability challenges that most models, including those by Evans et al. (2017), leave unaddressed. This gap underscores the need for frameworks that balance economic goals with environmental responsibility, an area where current literature is notably silent.

4.7 Performance Management Framework: Missing Component

The absence of a comprehensive performance management framework within legacy IoT models presents a significant limitation. The current models lack mechanisms for real-time monitoring of value co-creation, inter-organizational accountability, and adaptive response to emergent market or technological shifts. In the context of 5G IoT, the ecosystem becomes

increasingly complex, requiring models that can evaluate not just the performance of the focal firm but also the collective orchestration of ecosystem actors (Teece, 2018; Vargo & Lusch, 2016).

4.8 Implications of the Gap

The inadequacies of current IoT business models for 5G environments have far-reaching implications, as they fail to address several critical areas:

- **New Revenue Streams:** 5G's speed and edge computing capabilities enable real-time data services, such as dynamic pricing for autonomous fleets or instant analytics for smart manufacturing. Existing models like data monetization (Li & Xu, 2013) do not fully exploit these opportunities, as they were not designed for 5G's real-time, high-volume data environment.
- **Scalability for Massive IoT:** The mMTC feature of 5G supports millions of devices per square kilometer, overwhelming traditional subscription or platform models (Hodapp et al., 2019) that assume smaller-scale deployments. This scalability gap limits the ability of current models to handle the density and diversity of 5G IoT use cases.
- **Mission-Critical Applications:** URLLC enable applications requiring strict service level agreements, such as remote surgery or autonomous driving. Customer-centric models (Keiningham et al., 2020) do not yet accommodate these demands, as they lack the flexibility to ensure reliability and performance under 5G's stringent conditions. To unveil the real-world potency of URLLC in 5G IoT, one may consider five ultra-remote robot-assisted hepatobiliary and pancreatic surgeries executed across a 5,000-km span in China during February to September 2023. Operating one surgical console in Hangzhou and another in Alaer (Xinjiang), the team achieved median network latency of ~73 ms, zero packet loss, and minimal intraoperative blood loss (median 2mL). All patients recovered uneventfully, highlighting both the feasibility and safety of leveraging 5G-mediated remote surgery in clinical care environments (Fan et al., 2025).
- **Performance Management:** This is a core enabler of effective 5G IoT business models, supporting alignment across ecosystem actors, adaptive orchestration, and data-driven responsiveness. Beyond firm-level KPIs, it requires dynamic, co-created metrics that reflect interdependencies, guide strategic action, and strengthen trust and accountability. Embedding performance intelligence enhances dynamic capabilities and sustains competitive advantage in complex, evolving 5G IoT ecosystems.

Unlike 4G or earlier technologies, 5G supports real-time, mission-critical applications that redefine the IoT landscape. This shift necessitates dynamic business models capable of evolving with new roles, partnerships, and value chains capabilities that existing research does not adequately cover. The inability of current models to adapt to these demands actually risks stifling the transformative potential of 5G IoT. As such, existing IoT business models demonstrate limited suitability for ecosystem performance governance, thereby undermining

their applicability in the 5G context where value is emergent, relational, and dynamic. This gap calls for rethinking performance management not as a supporting function, but as an integral element of business model design in the 5G IoT era.

5. Conclusion

The reviewed articles, ranging from Chesbrough and Rosenbloom (2002) to Shafique et al. (2020), provide a rich foundation for understanding IoT business models, with insights into value creation, ecosystems, technology integration, customer focus, and sustainability. However, a critical gap persists: these models are predominantly rooted in pre-5G contexts and fail to address how 5G's unique features in massive connectivity, ultra-low latency, and edge computing necessitate adaptation. This disconnect is evident across infrastructure limitations, unexplored data opportunities, complex ecosystem dynamics, financial and operational challenges, and regulatory and sustainability oversights.

Future research must explore how IoT business models can evolve to leverage 5G's capabilities fully, ensuring they support new revenue streams, massive scalability, and mission-critical reliability in an increasingly connected world. The business model frameworks for 5G IoT should explicitly embed performance management capabilities that span firm boundaries, facilitate adaptive orchestration, and align with the underlying principles of resource-based and ecosystemic strategy. Specifically, researchers should investigate how 5G's features, such as network slicing and edge computing, can be integrated into adaptive business models to address scalability and interoperability challenges (Mahesh & Bhargava, 2025). Moreover, exploring intelligent automation and data-driven ecosystems can enable CSPs to reconfigure resources dynamically, creating value through new revenue streams and enhanced reliability (Attaran, 2023). Only through the development of comprehensive, adaptable frameworks can the transformative potential of 5G IoT be realized, aligning business strategies with technological advancements. This evolution is essential to bridge the gap between current models and the demands of 5G, enabling businesses to thrive in this next-generation landscape.

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Appendix A

Elements in IoT Business Model Literatures

Author, Year	Business Model Elements																		Country of Study
	Value propositions	Customer relationships	Channels	Key resources	Key activities	Key partnerships	Customer segments	Revenue streams	Cost structure	Ecosystem	Digital transformation	Servitization	Data analytics	Security	Privacy	IT integration	Network effects	Stakeholder integration	
Westerlund et al. (2014)	✓	✓	✓							✓	✓								Finland
Chesbrough and Rosenbloom (2002)								✓		✓	✓								USA
Gassmann et al. (2019)										✓	✓								Switzerland
Bilgeri et al. (2015)										✓	✓								Switzerland
Palattella et al. (2016)		✓	✓	✓						✓	✓								Luxembourg/UK
Hodapp et al. (2019)			✓				✓			✓	✓								Germany
Chan (2016)	✓				✓		✓												Hong Kong
Bucherer and Uckelmann (2011)	✓			✓		✓													Germany
Lindgren and Rasmussen (2013)				✓			✓			✓	✓								Denmark
Li and Xu (2013)			✓			✓		✓											China
Dijkman et al. (2015)							✓	✓											Netherlands

Author, Year	Business Model Elements																		Country of Study
	Value propositions	Customer relationships	Channels	Key resources	Key activities	Key partnerships	Customer segments	Revenue streams	Cost structure	Ecosystem	Digital transformation	Servitization	Data analytics	Security	Privacy	IT integration	Network effects	Stakeholder integration	
Endres et al. (2019)				✓		✓													Germany/Australia
Fleisch et al. (2015)				✓	✓		✓												Switzerland
Tesch et al. (2017)	✓					✓		✓											Switzerland
Ju et al. (2016)	✓	✓		✓															South Korea
Keiningham et al. (2020)	✓	✓	✓																USA
Chiang and Zhang (2016)				✓	✓		✓												Finland
Gierej (Gierej, 2017)	✓				✓		✓												USA
Lee and Lee (2015)	✓			✓			✓												Switzerland
Leminen et al. (2018)	✓					✓	✓			✓	✓								Germany
Muller et al. (2018)	✓			✓			✓												Italy
Oughton and Frias (2018)			✓	✓	✓														Germany
Rao and Prasad (2018)	✓			✓	✓														Hong Kong
Shafique et al. (2020)	✓	✓	✓																Germany

Author, Year	Business Model Elements																		Country of Study
	Value propositions	Customer relationships	Channels	Key resources	Key activities	Key partnerships	Customer segments	Revenue streams	Cost structure	Ecosystem	Digital transformation	Servitization	Data analytics	Security	Privacy	IT integration	Network effects	Stakeholder integration	
Gupta and Jha (2015)			✓	✓		✓													Sweden
Amit and Zott (2010)				✓	✓		✓				✓					✓			China
Boons and Lüdeke-Freund (2013)	✓	✓				✓											✓	✓	Netherlands
Turber et al., (2014)	✓			✓	✓								✓	✓	✓				Germany
Lehoux et al. (2014)	✓	✓						✓				✓	✓						Switzerland
Metallo et al. (2018)			✓	✓	✓														Germany
Total	15	7	9	15	9	7	11	5	0	8	9	1	2	1	1	1	1	1	

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