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The evolution of Internet of Things (IoT) research in business management: a systematic review of the literature

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Abstract

Purpose – This paper systematically reviews the evolution of Internet of Things (IoT) research in business and management over the past decade and a half. It synthesizes current knowledge, identifies major themes, gaps, and future opportunities to guide scholars on potential research directions within this exponentially growing domain.
Design/methodology/approach – A structured systematic literature review methodology filtered IoT publications across business/management journals using Scopus database. Detailed thematic and bibliometric analyses chronologically mapped the progress of peer-reviewed articles from 2005–2023. Both quantitative metrics and qualitative coding inductively revealed historical trends, topics, applications and research implications.
Findings – Analysis uncovered six primary IoT research themes - business models, technology, data, customers, organizations, and sustainability. Dominant focuses were found on technological enablers, business model innovation and customer experience transformations. While technical aspects are well-documented, strategic technology integrations and organizational change management require greater emphasis.
Research limitations/implications – Focus restricted to academic articles published in management journals risks missing relevant papers published in other fields. Screening process involved some subjectivity. Lacks geographic analysis of research contexts. The rapidly evolving nature of technology domain risks findings' generalizability.
Practical implications – Key enablers and success factors that we identified may support managerial decision making when it comes to IoT adoption.
Social implications – We discuss advancing IoT innovation through ethics and sustainability lenses and these may help ensure responsible adoption.
Originality/value – This analysis weaves together the extant literature and offers an evidence-based research agenda for management scholars by chronicling the state, evolution, influential factors, and future opportunities within IoT literature. It highlights major thematic shifts and priority gaps to address.

Keywords Internet of Things, IoT, Bibliometric analysis, Thematic analysis, Technology management, Information systems

Paper type Literature review

1. Introduction

The Internet-of-Things (IoT) (Wortmann and Fluchter, 2015; Xia *et al.*, 2012) can be generally defined as a system or network of digitally connected devices that share data and

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communicate with each other (Burgess, 2018; Lee and Lee, 2015). This system is usually supported by technological components such as wireless sensors, software applications, cloud computing and radio frequency identification devices (RFID) that jointly create value for the participants (Ikavalko *et al.*, 2018; Lee and Lee, 2015).

IoT continues to be a "hot" topic of study among the scholarly community, partly due to an explosion of IoT adoption around the world at both organizational and individual levels over the last several years, and partly due to IoT's multidimensionality and versatility, which make it relevant for a vast variety of fields. The academic literature on IoT has been burgeoning at a rapid pace, wherein IoT is conceptualized from a variety of viewpoints and studied in varied contexts due to its multidimensional nature (Delgosha *et al.*, 2021; Ng and Wakenshaw, 2017). However, certain topics (e.g., smart cities; business process IoT) occupy a relatively larger proportion of the literature (see Delgosha *et al.*, 2021) resulting in blurred definitional boundaries and ambiguity on what constitutes IoT research in the management/business domain. Moreover, the largest literature on this topic, which is produced by scholars in the *I.T./software engineering* and *industrial/manufacturing/operational* fields, is micro-level and exclusive to the highly technical aspects of specific IoT applications, making it difficult to apply or examine it in the *management/business* domain. Meanwhile, with rapidly growing, widespread applications of IoT by mainstream businesses for mass consumption, both the relevance and significance of IoT for management/business scholars has increased tremendously over the years. However, barring a few notable efforts (e.g., Delgosha *et al.*, 2021; Sestino *et al.*, 2020), there is still a major dearth of information to guide and inform scholars of management/business on fruitful research avenues in IoT. The present research is an effort to fill that gap. Using a four-step structured process similar to Palmaccio *et al.* (2021), we conduct a systematic literature review (SLR) of IoT in the management/business domain supported by a detailed thematic- and keyword analysis to create a comprehensive IoT research agenda for management/business scholars.

The need for an IoT literature review is timely due to the rapid pace at which the literature is growing in terms of the sheer number of publications, which means that new insights and revelations about IoT are being uncovered rapidly, thereby necessitating corresponding literature reviews to keep the scholars abreast of the latest developments in the field. Additionally, the currently available literature reviews of IoT are mostly found covering a period until 2019, thereby necessitating additional examination of subsequently published articles.

In summary, while the number of IoT publications in the management/business journals have grown exponentially – particularly during the last three years – the efforts to perform a systematic review of this literature have not kept pace. The present paper aims to fill this gap by doing a longitudinal analysis of the last 18 years of IoT research in management/business to address the following research questions:

RQ1. How has IoT research in the Management/Business domain evolved over the years?

RQ2. What is the current state of IoT within the Management/Business field in terms of its major themes and the topics of study within each?

RQ3. Going forward, which research areas and research questions represent fruitful opportunities for Management/Business scholars of IoT?

An SLR is considered ideal for this study because of its methodological rigor (Okoli and Schabram, 2010) and its goal of "[. . .] identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners." (Fink, 2005, p. 3). Moreover, an SLR is considered most appropriate when the aim of a study extends beyond merely aggregating all the information about a research question to

developing evidence-based guidelines for future research (Lenberg *et al.*, 2015; Kitchenham *et al.*, 2009; Palmaccio *et al.*, 2021). The present study conducts thematic- and keyword analysis to identify major research themes and study-areas pervading the management/business IoT literature and derive from them valuable topics of inquiry that can guide future research.

The remainder of the paper is structured as follows: Section 2 introduces a theoretical background on IoT and provides a synopsis of management/business research in this area. Section 3 explains the methodology followed in conducting the SLR. Section 4 presents the results and their application to the research questions. Finally, section 5 discusses the implications and contributions of this study along with suggested pathways for future research.

2. Background

2.1 An overview of IoT research

The first known use of the term "internet-of-things" dates back to 1999, when Kevin Ashton, an employee at Proctor and Gamble used it in his presentation about RFID tags (Ashton, 2009; Rayome, 2018). Till date, no universally accepted definition exists for the term (Wortmann and Fluchter, 2015); resulting in varied conceptualizations adopted by academicians, scholars, practitioners, programmers, and business executives who continue to pursue their own versions of its meaning (Madakam *et al.*, 2015; Ng and Wakenshaw, 2017; Nord *et al.*, 2019). However, a generally accepted conceptualization of IoT is that of a multilayered network of machines and devices connected through the internet with the goal of generating and sharing data (see Nord *et al.*, 2019). This broad conceptualization has allowed scholars and practitioners in a variety of domains to examine IoT from different research lenses. However, it has also resulted in IoT literature evolving into "*a mass of disorganized knowledge*" and "*multiple, yet inconsistent paths*" (Sestino *et al.*, 2020, p. 1).

From an evolutionary standpoint, two primary and well-established streams of scholarly research exist on IoT – 1) the *I.T./software-engineering* stream, and 2) the *Industrial/manufacturing/operational* stream. The focus of our study is on a *third*, yet nascent, but rapidly growing stream of *Management/business* research on IoT, which exists at the intersection of the two aforementioned streams.

IoT being inherently comprised of digital architectures, the literature on IoT originally emerged in the *I.T./software engineering* domain where it has been studied from a technical perspective (e.g., Madakam *et al.*, 2015; Gubbi *et al.*, 2013; Laghari *et al.*, 2021) with the scholarly focus mainly on aspects such as its architectural elements (e.g., Al-Qaseemi *et al.*, 2016; Soumyalatha, 2016), Radio Frequency Identification (RFID) tags (e.g., Jia *et al.*, 2012), Wireless Sensor Networks (WSN) (e.g., Kocakulak and Butun, 2017), and such. Here, scholars have uncovered valuable insights on the privacy, security, and trust related issues in IoT (e.g., Assiri and Almagwashi, 2018; Noor and Hassan, 2019; Stergiou *et al.*, 2018; Tewari and Gupta, 2020).

Later, the growing implications and usage of IoT for industrial processes led to the emergence of the *industrial/manufacturing/operational* stream of IoT research – commonly known as the *Industrial Internet of Things* (IIOT) (Boyes *et al.*, 2018; Sisinni *et al.*, 2018; Madakam and Uchiya, 2019) – which focused on topics such as smart production processes (e.g., Zhang *et al.*, 2018), intelligent automation and assembly (e.g., Liu *et al.*, 2017), industrial safety (e.g., Gnoni *et al.*, 2020; McNinch *et al.*, 2019), and such. The emphasis here is on the role of IoT in improving operational processes in industrial spaces. However, this stream of IoT research is not just limited to the manufacturing sector – healthcare, agriculture, transportation, construction and environment sectors have all benefitted from advances in *Industrial IoT* (Fraga-Lamas *et al.*, 2017; Malik *et al.*, 2021; Qamar *et al.*, 2018).

Subsequently, the expansion of IoT applications beyond the I.T. and industrial processes and into mainstream businesses (for example, the growing consumer market for smart

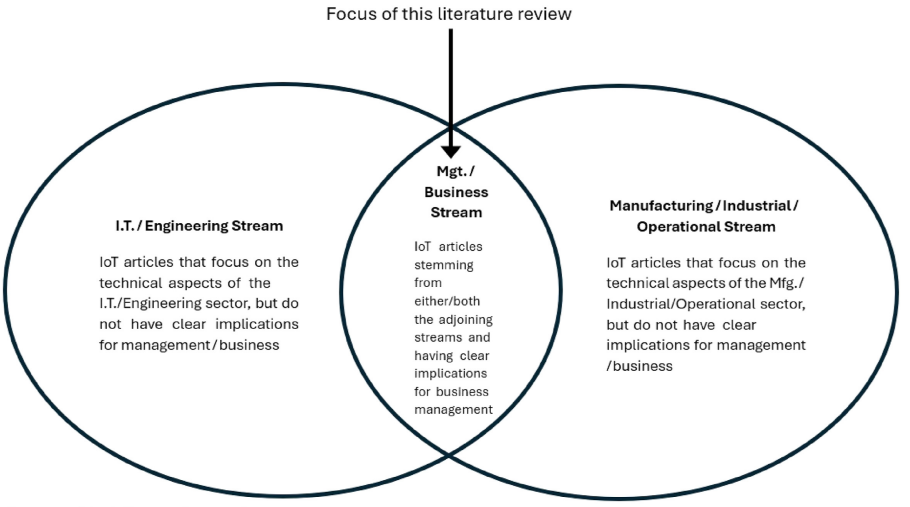
watches and smart home security systems) has attracted considerable interest and attention from scholars in the traditional *management/business* field. However, this stream of IoT research, being relatively nascent, is still fragmented and devoid of boundary conditions. It also continues to borrow heavily from the other two streams (viz., *I.T./engineering* and *industrial/manufacturing*). In this manuscript, our focus is on developing a review-based future research agenda for scholars of this *third* stream of research.

Figure 1 visually depicts our area of inquiry in this manuscript. It indicates that the relatively nascent literature on management/business IoT research has emerged primarily at the intersection of the engineering and industrial domains.

2.2 IoT research from a management/business perspective

From a practical, real-life standpoint, the widespread influence and application of IoT in business and management practices can be readily explained via a few brief case examples: 1) In the financial services and banking sector, IoT is transforming the traditional business payments/ordering systems via increasing use of digital wallets and contactless payments (Agrawal, 2021; Singh, 2019) where devices such as smartphones serve as "secure wallets" capable of paying and receiving digital currency. This example highlights the value that IoT generates for businesses in their core functions such as sales and order processing. 2) From the standpoint of organizational decision-making, particularly in large firms dealing with big data, IoT is assisting managers in making effective decisions in asset management and resource allocations (Brous *et al.*, 2017, 2019). Subsequently, in several mainstream enterprises, IoT is increasingly becoming pivotal for business processes in asset- and resource-management. 3) In the consumer electronics sector, IoT-based "smart" wearables and home security devices highlight the penetration and significance of this technology in the final product/service of a business (Singh and Majumdar, 2018) and show how IoT is increasingly becoming a core component of a business's ultimate value offering, thereby directly affecting its bottom line and revenues.

Subsequently, the *management/business* scholars view IoT mainly as a driver of value creation and value capture in business (Metallo *et al.*, 2018; Lee and Lee, 2015; Saarikko *et al.*,



Source(s): Figure by authors

Figure 1.
Scope of this Study in the Context of Broad IoT Research

2017) with focus on topics such as new business opportunities and product development (e.g., Del Giudice, 2016; Krotov, 2017), business model innovation (e.g., Haaker *et al.*, 2021), consumer electronics (e.g., Gaur *et al.*, 2019; Singh and Majumdar, 2018), building customer profiles (e.g., Zare and Honarvar, 2021), and such.

One of these areas of research, namely, IoT business model innovation has been a prominent and recurring theme of research in the management/business domain (ref., Delgosha *et al.*, 2021; Dijkman *et al.*, 2015; Palmaccio *et al.*, 2021; Metallo *et al.*, 2018). Scholars in this area are involved in examining how IoT can influence and/or transform the core building blocks of an organization's business model canvas and have found that it has the potential to positively influence a business's value proposition, key partners, customer relationships, key resources, key activities, market segments, and cost as well as revenue structures (Dijkman *et al.*, 2015; Metallo *et al.*, 2018).

In another sub-stream which can be referred to as the consumer electronics area, research has made significant forays into various aspects related to the security features, privacy issues, and technology vulnerabilities in IoT products (e.g., Alladi *et al.*, 2020; Blythe *et al.*, 2019; Meng *et al.*, 2018; Loi *et al.*, 2017; Poyner and Sherratt, 2018; Ren *et al.*, 2019; Shakdher *et al.*, 2019; Williams *et al.*, 2017). The focus of this set of scholars has been to improve the security and reliability of IoT products by identifying and highlighting the existing issues and subsequently suggesting solutions to resolve them.

Another sub-stream has explored the technology and social acceptability of "smart wearables" (a class of IoT products) (e.g., Dagher *et al.*, 2020; Niknejad *et al.*, 2020; Dian *et al.*, 2020; Motti and Caine, 2016; Li *et al.*, 2019; Oh and Kang, 2021; Qiu *et al.*, 2017; Sun *et al.*, 2017). Here, the researchers have investigated the potential role and impact of emerging technologies and their associated factors on the social adoptability of IoT products, specifically in the "wearables" market such as gadgets, accessories, and garments. This branch has also extended to IoT's adjacent domains such as artificial intelligence (AI) (Shi *et al.*, 2020; Zheng *et al.*, 2021), big data analytics (Li *et al.*, 2021), and virtual reality (Alshaal *et al.*, 2016).

Yet another research branch has focused on the user/consumer profile in the IoT ecosystem. Here, the focal topics of study have been the roles, perceptions, experiences, expectations, and behaviors of users/consumers in relation to IoT products (e.g., Aldossari and Sidorova, 2020; Al Hogail and Al Shahrani, 2018; Blythe and Johnson, 2018; Curry *et al.*, 2018; De Boer *et al.*, 2019; Fauquex *et al.*, 2015; Park *et al.*, 2017; Yerpude and Singhal, 2018). Scholars involved in this stream have uncovered valuable insights regarding the antecedents to IoT adoption (e.g., Aldossari and Sidorova, 2020) and factors affecting user experience (e.g., Curry *et al.*, 2018).

Each of the aforementioned research sub-streams has been growing steadily over the recent years with newer "sub-components" emerging at a continued pace.

2.3 The need for a literature review of IoT in management/business

Despite boasting a substantial body of work showing the implications of IoT for core management/business outcomes, this literature is still in need of establishing clear boundary conditions to qualify as a cogent, standalone stream of IoT research. A literature review is critical to the establishment of such boundary conditions. As Lim *et al.* (2022; *p.486*) state, "*literature reviews are necessary to take stock of the field (e.g., major themes) in order to chart the future trajectory of that field. This helps prospective scholars interested in that field to better position future research in terms of which exact stream(s) out of the many streams of research in that field that they wish to extend.*" Thus, a *management/business*-specific literature review of IoT research would significantly advance the research agenda for future management/business scholars. However, while several comprehensive literature reviews in the *I.T./*

engineering and *industrial/manufacturing* domains have encapsulated the research on IoT and helped set up boundary conditions for those domains (see Madakam *et al.*, 2015; Laghari *et al.*, 2021; Čolaković and Hadžialić, 2018; Liao *et al.*, 2018; Malik *et al.*, 2021), the same does not hold true currently for the *management/business* domain.

Except for the review by Delgosha *et al.* (2021) (which is noteworthy, but quite broad in its scope and therefore not strictly "management/business-oriented"), there is a lack of overarching literature reviews capturing the noteworthy scholarly work on IoT by management/business scholars. Those that have uncovered valuable insights in this area have focused on a *single theme* within IoT such as the benefits/risks of IoT adoption (e.g., Brous *et al.*, 2020), IoT business models (e.g., Palmaccio *et al.*, 2021), IoT servitization (e.g., Suppatvech *et al.*, 2019), IoT business process management (BPM) (e.g., De Luzi, Leotta, Marrella, 2024), IoT supply chain management (SCM) (e.g., Rebelo *et al.*, 2022), and such. As a result, an *overarching* review of the IoT literature (comprising multiple themes) within the management/business domain is still largely nonexistent. Lastly, due to the rapid growth of IoT research, certain insightful reviews published almost a decade ago (e.g., Djikman *et al.*, 2015) run the risk of becoming obsolete, necessitating a fresh examination of the literature. Hence, the time is opportune for a literature review to examine and synthesize the existing work on IoT in the management/business area.

3. Methodology

The purpose of this study was to evaluate IoT research in management/business domain in terms of its scope, volume, boundary conditions, major topics/areas of study, and gaps therein with an aim to advise future research on this subject. To do so, we conducted an SLR based on the guidelines provided by Okoli and Schabram (2010) and Xiao and Watson (2019). Additionally, the study followed the structural aspects of prior SLRs in the software industry such as Brereton *et al.* (2007) and Manikas and Hansen (2013) since IoT falls within the purview of information technology (I.T.).

An SLR was considered the best approach for this study because of its ability to cohesively synthesize the dispersed research findings on a topic and generate meaningful insights from them that can help future research (Kraus *et al.*, 2020; Okoli, 2015; Palmaccio *et al.*, 2021). Subsequently, our SLR followed a structured process consisting of the below listed four (4) major steps as suggested in the literature (Tranfield *et al.*, 2003; Lu *et al.*, 2018; Palmaccio *et al.*, 2021):

(1) Planning the review

(2) Finding and evaluating the articles

(3) Deriving and compiling the data

(4) Reporting the results

This predefined process ensured the reproducibility of the SLR and reduces bias during the review process (Tranfield *et al.*, 2003; Kraus *et al.*, 2020; Palmaccio *et al.*, 2021). Specifically, we followed the systematic process adopted by Palmaccio and colleagues (2021) in their SLR of IoT business models.

3.1 Planning the review

After validating the need for an SLR (explained earlier), we began by creating a review protocol to ensure the transparency and replicability of the review process. We chose the Elsevier's Scopus database to search for the relevant articles and validated them using the Google Scholar database. Scopus is one of the largest and widely reputable multidisciplinary

repositories of published research and has been used extensively by scholars to conduct similar literature reviews (e.g., Borges *et al.*, 2021; Reim *et al.*, 2015; Henriette *et al.*, 2015). The database is admired among the research community for its comprehensiveness, the relevancy of its search-results, and the accuracy of its filtering processes (e.g., Mahraz *et al.*, 2019; Reim *et al.*, 2015; Sestino *et al.*, 2020). Specifically, prior research on digital technologies has used Scopus extensively (e.g., Borges *et al.*, 2021; Henriette *et al.*, 2015; Mahraz *et al.*, 2019; Palmaccio *et al.*, 2021; Sestino *et al.*, 2020), which makes it particularly relevant for our study.

The goal of our review was to synthesize current knowledge on the business and management impacts of Internet of Things (IoT) guided by research questions on the state, topics, influential factors, and future opportunities of IoT research. Subsequently, peer-reviewed articles published in the last fifteen years examining managerial/organizational IoT implications were included in the study. Non-peer reviewed articles focused solely on technical aspects were excluded. We restricted our search to journals primarily in the areas of business and management (including management of information systems). The Scopus database was searched using "IoT" and relevant business terms. Extracted data encompassed article metadata, IoT technologies, business functions impacted, implementation issues, findings, and future research needs. Qualitative analysis coded patterns on IoT topics, challenges, successes, and research gaps. Quantitative analysis assessed publication and research trends.

3.2 Finding and evaluating the articles

Scopus journal database was systematically searched for English articles from 2005–2023 combining "IoT" with business terminology. The list of journals to be searched was derived from the Business and Management classification of the SCOPUS database. A total of 105 journals in Business/Management containing over 1200 articles were found to be relevant to our study. Subsequently, we searched these journals with the search keywords for our study. The key search terms included "internet of things" OR IoT AND manage* OR busi* OR organiz* OR compan* OR corporat* OR enterprise. This resulted in 52 journals with 351 articles containing the search term in either the title, keywords or abstract of the article. The other 53 journals did not return any results for the IOT key terms search and were removed from further consideration. For each of the 351 articles, we read and screened the title and abstract to identify and further filter the relevant articles that met the goals of our research. Articles that did not have IoT as one of the central themes or topics were removed from further consideration. Besides, articles focused on IoT but not relevant to management/business and/or not having a clear business implication for value creation or value capture were also removed from further consideration, since that was our defining criteria for IoT in management/business as explained earlier. The filtering resulted in a final set of 326 articles from 41 journals that were relevant to the purpose of our study. This final set of 326 articles meeting all relevance and quality inclusion criteria were moved forward to the data evaluation and extraction stage. A PRISMA process tracked the screening and selection process, showing the iterative filtering to obtain the final literature sample.

3.3 Deriving and compiling data

Key data points were extracted. Metrics compiled included publication volume trends, research methods used, and frequency of business areas, and the IoT technologies studied.

3.4 Reporting the results

Reporting aligned to each research question and the analysis was predominantly qualitative. Reporting followed generally accepted systematic review guidelines. Varied analytic approaches provided robust, structured insights for management scholars on the IoT domain.

4. Results

While IoT as a concept has been in existence since almost a quarter of a century, largely in the domains of information technology and computer science, its relevance for and applications in the field of business have been relatively nascent. The results of our literature review revealed that the research on IoT in the business/management area – although nascent – is growing at a rapid rate. In terms of the volume of publication by outlets, significant variation was found between the articles published in top-tier versus lower-tier business/management journals. Specifically, higher ranked business publications were found to publish significantly fewer articles on the topic compared to relatively lower ranked business journals. We also observe noteworthy absences of IoT related themes in top-tier journals such as the *Academy of Management Journal*, the *Academy of Management Review*, and the *Journal of Management*, and only a single publication for the *Strategic Management Journal*. On the other hand, journals ranking on a comparatively lower tier such as the *Journal of Business Research* and the *International Journal of Information Management* had an exponentially high volume of publications on the topic. This difference underscores the relatively nascent nature of IoT in the business/management field because a sound theoretical foundation and methodological rigor are two criteria upheld by the higher ranked journals, and business/management research on IoT still has considerable progress to make in fulfilling both those criteria.

In the ensuing sections, we provide the results of the SLR in response to our research questions that were derived from the thematic and bibliometric analysis of the articles reviewed in our study. Initial thematic analysis based on inductive coding revealed several areas of IoT application in the business/management domain that were classified into six (6) primary themes, namely, 1) Business models and strategy, 2) Technology and infrastructure, 3) Data and analytics, 4) Customers and markets, 5) Organizations and work, and 6) Sustainability and environment. Major research streams within each of those six themes were further categorized into a total of 27 different sub-topics.

The examination of our first research question – the evolution of IoT research in the Business/Management domain over the years – was carried out by corresponding the results of the thematic analysis with the order (year wise) of IoT publications in our sample of articles. The resulting timeline provided below describes the major themes in IoT research from a historical standpoint starting at year 2000 and continuing beyond 2021 in 5-year segments.

Major Themes in IoT Research (2000–2005)

(1) Early Conceptualization of IoT: During this period, the concept of IoT was still in its infancy. Research focused on exploring the possibilities and defining what IoT could be, how objects could be connected to the internet, and potential applications. RFID technology received significant attention as a key enabler for IoT.

Major Themes in IoT Research (2006–2010)

(1) Technological Foundations and Protocols: This period saw increased interest in the technological infrastructure required for IoT, such as wireless sensor networks (WSN), communication protocols, and data transmission standards. Researchers were looking into how devices could effectively communicate and share data.

(2) Security and Privacy Concerns: As the IoT concept gained traction, discussions began on the potential security risks and privacy implications of having numerous devices connected to the internet.

Major Themes in IoT Research (2011–2015)

(1) Standardization and Interoperability: There was significant research into creating standardized frameworks and ensuring interoperability among IoT devices, considering the vast heterogeneity in device functions, manufacturers, and purposes.

(2) IoT in Industry (Industry 4.0): The term "Industry 4.0" started to become popular, and IoT was recognized as a key component. Researchers explored the integration of IoT into manufacturing, inventory-management and industrial processes, known as the Industrial Internet of Things (IIoT), with implications for several fields such as healthcare, energy, retail, transportation, etc.

(3) Smart Environments: The rise of smart homes, smart cities, and connected vehicles became prominent themes, with research focused on how IoT can improve efficiency, safety, and the overall quality of life.

Major Themes in IoT Research (2016–2020)

(1) AI and Machine Learning Integration: The latter half of the 2010s saw a push towards incorporating AI and machine learning with IoT, with research exploring how these technologies could enable smarter decision-making and predictive analytics in IoT systems.

(2) Edge and Cloud Computing: As the amount of data generated by IoT devices soared, research explored the role of edge and cloud computing in processing and storing this information efficiently.

(3) Blockchain for IoT: The potential of blockchain technology to secure IoT networks became a hot topic, given its capability to provide decentralized security and trust in device interactions.

(4) Consumer IoT Adoption and Behavioral Studies: There was a shift toward understanding how consumers adopt IoT products and their behavioral responses to smart technology, alongside studies on the market and business models for IoT.

Major Themes in IoT Research (2021 and beyond)

(1) 5G and Connectivity Improvements: The deployment of 5G networks is expected to be a significant driver for IoT research, focusing on ultra-reliable low-latency communications and enhanced mobile broadband.

(2) IoT for Sustainable Development: IoT's contribution to sustainability and addressing global challenges like climate change, health crises, etc., is likely to emerge as a major theme.

(3) Advanced IoT Applications in Healthcare and Remote Monitoring: Given the COVID-19 pandemic, there is likely to be a surge in research revolving around the use of IoT for telehealth, remote patient monitoring, and contact tracing.

(4) Ethical AI and Trustworthy IoT Systems: As society becomes increasingly aware of the ethical implications of technology, there will likely be more research on developing trustworthy AI systems within the IoT ecosystem, emphasizing fairness, transparency, and ethics.

(5) Human-IoT Interaction: Understanding the nuances of human interaction with IoT systems, including home automation, smart wearables, smart sensors and assistive technology, and improving the user experience (UX) will be critical areas of research.

The results of a keywords bibliometric analysis showed progressive changes in the research interests and topics of business/management scholars of IoT over the years. Table 1 provides the details of keywords highlighting major research topics in IoT corresponding to each time-period covered in our review.

The focus of IoT research in business/management during its early years (2000–2010) was mostly restricted to its industrial operations and applicability, with topics such as RFID systems, smart grids, and supply chain integration prominent in the publications. During 2011–2015, the research emphasis shifted towards the topics of cloud computing, big data, and analytics. Researchers also started examining security and privacy concerns surrounding IoT applications and making initial forays into examining IoT from a customer standpoint (e.g., smart shopping). However, it was only in the second half of that decade (2016–20) that business/management research fully started to examine IoT from a B2C standpoint, focusing on topics such as smart homes, autonomous vehicles, augmented/virtual reality, and 5G communication. This time-period also witnessed the rise of powerful new digital technologies such as artificial intelligence (AI), machine-learning, and blockchains in the mainstream markets, and a corresponding rise in the number of business/management scholars studying them. Finally, since 2021, the post-COVID focus of IoT scholars has been on applications of IoT in healthcare, biosensors, quantum computing, robotics, automation, 6G networks, and brain-computer interfaces, among others. Furthermore, researchers have also started focusing on the ethical and sustainability aspects of IoT and AI.

Our bibliometric analysis also revealed variations in research topics by journal. Particularly, the articles in our 41 shortlisted journals for this review varied in their primary sub-topics of IoT, ranging from topics such as cybersecurity and logistics to smart grids and smart cities. The full list of major IoT topics found in each journal is provided in Table 2 below.

4.1 Overall major themes and subthemes

Our thematic analysis led to the identification of major themes across the period of study and also key elements within each primary theme, which are detailed below:

Business Transformation Focus:

(1) Servitization and Advanced Services: The way IoT assists manufacturers and B2B firms in shifting from product-focused to service-based models, encompassing remote monitoring, predictive maintenance, and data-driven optimization.

Years	Keywords
–2010	RFID systems, sensor networks, supply chain integration, inventory tracking, smart appliances, smart grids
2011–2015	Cloud computing, big data, data analytics, smart meters, smart shopping, IoT platforms, M2M communication, IoT security, IoT privacy, IoT inventory management
2016–2020	AI and machine learning, 5G and edge computing, blockchain, digital twins, autonomous vehicles and transportation, smart cities, smart homes, augmented and virtual reality, IoT security and privacy, APIs
2021-	6G networks, ambient intelligence, quantum computing, robotics and automation, brain-computer interfaces, biosensors, AI in healthcare, nanotech, home automation, holographics, circular economy, digital ethics, AI regulations (ethical, security, privacy aspects), IoT for sustainability

Source(s): Table by authors

Table 1. Keywords analysis for historical research topics in IoT

Journal	Keywords
Academy of Management Discoveries	blockchain, digital currencies
Academy of Management Perspectives	blockchain, governance
Academy of Management Proceedings	internet of things, value proposition
Annual Review of Organizational Psychology and Organizational Behavior	technology, work, organizations
Big Data and Society	smart sensors, smart homes, human-computer interactions, APIs for smart cities, data co-creation, IoT for sustainability
Business Horizons	dark data, internet of things, sensor-based entrepreneurship
Business Information Review	Smart libraries, automated work
Competition and Regulation in Network Industries	Smart grids/meters, AI regulations, 5G, smart cities
Decision Support Systems	events, internet of things
Entrepreneurship Theory and Practice	artificial intelligence, entrepreneurship
European Management Journal	blockchain, shipping industry
Global Business Review	Home automation, Smart cities
Industrial Marketing Management	smart products, business markets
Information and Organization	interfaces, internet of things
Information Processing and Management	blockchain, IoT, blockchain, industry 4.0
Information Systems Research	Data Analytics and Big Data, IoT Security and Privacy, IoT-enabled Business Models
International Journal of Engineering Business Management	Healthcare, IoT Inventory and Equipment Management, IoT for sustainability
International Journal of Information Management	smart warehousing, voice shopping, trust, privacy
International Journal of Management Education	online business education
Journal of Business Research	service encounter, smart goods, digital innovation, housing market, travel agents, sustainable development, blockchain, augmented reality, purchase intention, digital business
Journal of Business Venturing	maker movement, entrepreneurship, energy industry
Journal of High Technology Management Research	electronic money, healthcare
Journal of Industrial Information Integration	5G, internet of things, logistics, RFID, blockchain, industrial IoT, wireless sensor networks
Journal of Innovation and Knowledge	industry 4.0, decision-making
Journal of Interactive Marketing	analytics models
Journal of Management Studies	interorganizational, big data
Journal of Marketing	Smart shopping/carts, retail
Journal of Retailing and Consumer Services	smart parcel locker, logistics, internet of things, retail
Journal of the Academy of Marketing Science	in-store technology, retail
Journal of World Business	backshoring, industry 4.0
Long Range Planning	dynamic capabilities, digital transformation
MIS Quarterly: Management Information Systems	data analytics, asthma management, remote health, predictive analytics
Production and Operations Management	Smart Manufacturing and Industry 4.0, Supply Chain Optimization, Predictive Maintenance
Organization and Environment	consumer trust, energy utilities
Research Policy	smart card
Socio-economic Planning Sciences	internet of things, healthcare
Strategic Entrepreneurship Journal	disruptors, entrepreneurial change
Strategic Management Journal	platform creation
Technology in Society	internet of things, technology acceptance, brain-machine interfaces
Technovation	platform competition, internet of things
Transportation Research, Part E	cybersecurity, logistics

Table 2.
Major keywords in each journal

Source(s): Table by authors

(2) Innovation in Business Models: The transformation of conventional business models across sectors through IoT-enabled offerings, digital servitization, and platform-centric models.

(3) Sustainability and Circular Economy: The use of IoT in circular economy strategies, the attainment of sustainable development objectives, and the creation of sustainable business models.

Organizational and Technical Factors:

(1) Impacts and Capabilities of Organizations: The investigation into changes in company boundaries, knowledge flows, and the ambidextrous abilities needed for successful IoT integration.

(2) Smart Manufacturing and Industry 4.0: The application of IoT, data analytics, and AI in smart manufacturing, cyber-physical systems, and the realization of Industry 4.0 objectives such as efficiency, flexibility, and predictive maintenance.

(3) Technical Architecture and Security: The examination of robust IoT architectures, wireless communication technologies (like 5G), protocols, and data management solutions for dependable and secure systems.

User-Centric Applications and Effects:

(1) Consumer Behavior and Intelligent Products: The comprehension of user perceptions, value evaluations, and brand preferences in relation to smart products and services.

(2) Enhancement of Customer/User Experience: The use of IoT for personalization, customization, and innovative devices/interfaces such as wearables and conversational agents to boost customer loyalty and engagement.

(3) Smart Monitoring and Applications: The emphasis on IoT applications in healthcare, smart homes/cities, tourism, and energy management, enabling remote monitoring, assisted living, and intelligent services.

Challenges and Emerging Technologies:

(1) Challenges in IoT Adoption: The addressing of technological, privacy, security, legal, and regulatory barriers, as well as the lack of standards and interoperability issues.

(2) IoT and Emerging Technologies: The analysis of the synergy between IoT and technologies like AI, blockchain, cloud computing for the construction of smart systems and value extraction.

(3) Data Analytics and Insights: The utilization of IoT data for effective data acquisition, analytics, and actionable insights for improved decision making, prediction, and monitoring.

Additional Themes:

(1) Collaboration among Stakeholders: The significance of collaboration and co-creation among multiple stakeholders in the design of successful IoT solutions.

(2) Ethical Considerations: The discussion of cybersecurity, privacy, and ethical risks associated with IoT data collection and usage, and the exploration of potential regulations and policies.

With respect to our second research question – the current state of IoT in business/management in terms of its major themes and areas of applicability – our analysis revealed the following important takeaways:

(1) IoT is driving business model innovation: This includes developing new services, transforming existing business models, and creating platform business models.

(2) IoT enables servitization and advanced services: IoT allows manufacturers to offer remote monitoring, predictive maintenance, and optimization services.

(3) IoT has a significant impact on organizational structures and capabilities: It influences firm boundaries, knowledge flows, and ambidextrous capacities.

(4) IoT is fostering integration with sustainability: It supports circular economy strategies, sustainable development goals, and sustainable business models.

(5) IoT has a wide range of applications across different sectors: This includes manufacturing, retail, transportation, logistics, healthcare, and smart cities.

(6) IoT involves various technical aspects: This includes wireless communication technologies, data management, and security.

(7) IoT brings security, privacy, and trust challenges: These challenges need to be addressed to ensure the safe and ethical use of IoT devices and data.

(8) Collaboration among stakeholders is essential for successful IoT implementation: This includes collaboration between businesses, governments, and consumers.

(9) The use of emerging technologies such as AI, blockchain, and cloud computing enhances IoT capabilities: This enables the development of smarter and more efficient IoT systems.

(10) IoT offers opportunities for new revenue streams and improved operational efficiency: This includes data monetization, platform business models, supply chain optimization, and predictive maintenance.

With respect to the third research question – future opportunities for business/management scholars of IoT – our review found several fruitful avenues and important gaps in the literature that could serve as viable opportunities for future research:

Firstly, two strong research streams already dominate the current extant IoT literature, where the business/management scholars can make a timely impact. The first is the role of technology enablers and business value drivers in successful IoT applications. This body of IoT literature reflects the current stage of IoT adoption, where understanding capabilities and applications is crucial. The insights gained from examining such enablers/drivers can help businesses understand and decide which technologies to invest in and how to implement them for maximum impact. The second dominant research stream is the set of organizational factors relevant for IoT adoption. Recognizing the challenges and solutions for successful IoT adoption is vital for overcoming practical implementation hurdles. Understanding and leveraging the key organizational factors in the process can guide businesses in building the necessary skills and structures to thrive in the IoT landscape. From the standpoint of future research opportunity, the business/management scholars of IoT may benefit from taking a deeper dive into the organizational adoption factors. While barriers are acknowledged, more research is needed on specific strategies for building IoT capabilities. This could include case studies of successful companies, best practices for talent acquisition and training, and frameworks for navigating organizational change.

Other timely opportunities for future research identified in our review include:

(1) Expanding the focus on strategic considerations: Sustainability, privacy, security, and consumer behavior are critical pillars for long-term success. More research is needed on integrating these considerations into IoT initiatives from the outset, alongside technology and value aspects. This could involve ethical frameworks for data usage, consumer trust-building strategies, and security vulnerability assessments.

(2) Exploring underrepresented domains: While applications in manufacturing, supply-chain and healthcare are crucial, exploring untapped potential in services, retail, media and entertainment can open new avenues for innovation and growth. Research could uncover unique use cases, business models, and challenges specific to these industries.

Some additional gaps in the current literature that can serve as fruitful opportunities for future research:

(1) Policies and regulations: Current IoT literature lacks a thorough understanding of the role of government policies and regulations in shaping IoT adoption and addressing its ethical concerns. While the modern innovation frontiers continue to expand and companies continue to push newer IoT and AI technologies into markets, the subsequent and necessary examination of their sociomaterial dynamics and their larger implications for the society are yet to be fully examined. Future scholars may benefit tremendously from examining IoT in the light of institutional regulations and its "true societal benefit". The potential "dark side" of IoT is still a relatively unexplored phenomenon and could lend itself to be a potent research stream for future scholars of IoT.

(2) Cultural and social factors: While IoT can and does have an impact on societies and cultures, the reverse may also be true, especially with respect to the adoption and acceptance of IoT technologies. A potentially fruitful avenue of future research would be to examine the impact of cultural and social factors (including demographic and economic sub-components) on consumers' acceptance and adoption of newer IoT technologies. One approach to examining this research area could be through the lens of interdisciplinary theories (such as the *diffusion of innovations* theory of marketing) to see if conventional theories of product diffusion and adoption apply to digital/IoT products.

(3) New technologies redefining the very scope of IoT: Another research area worth examining is the ongoing evolution of new technologies and their potential to further enhance and redefine the IoT landscape. Rapidly evolving technologies such as AI, robotics, and virtual reality are constantly pushing the boundaries of the IoT domain, and particularly with the growing efforts targeting novel interactions of such technologies (e.g., using application programming interfaces (APIs) to make AI perform more advanced tasks), it is necessary to continuously reexamine the traditionally accepted roles, definitions and boundary conditions of IoT to ensure that they keep pace with the rapidly evolving IoT architecture and its various components. Scholars may benefit from examining the advancements in IoT at the intersection of its supporting technologies.

From the above, it is somewhat evident that the current research progress of IoT in business and management demonstrates a multifaceted approach, encompassing both transformative business aspects and technical considerations. There's a strong focus on business transformation, particularly in the areas of servitization, business model innovation, and

sustainability. The research has progressed from exploring basic IoT infrastructure to investigating complex organizational impacts and technical architectures required for Industry 4.0 and smart manufacturing. User-centric applications have gained significant attention, with emphasis on consumer behavior, customer experience enhancement, and smart monitoring across various sectors. The field is actively grappling with adoption challenges, including technological, privacy, and security issues, while also exploring synergies with emerging technologies like AI and blockchain. Data analytics has emerged as a crucial area, focusing on extracting actionable insights from IoT data. Recent research has begun to address collaborative and ethical aspects of IoT implementation, though these areas, along with comprehensive governance frameworks, remain underexplored.

Table 3 presents a systematic summary of these themes, associated sub-themes, current research status, and gaps:

5. Discussion

This systematic review offers valuable insights into the evolution of IoT research in the business and management domain over the past one and a half decades. Our analysis reveals a rapidly accelerating pace of scholarship, with exponential growth in publications since the mid-2000s, coinciding with the expanding real-world adoption of IoT across industries and consumer segments. This trajectory points to a field still gaining momentum both in practice and research, reflecting the dynamic nature of IoT and its far-reaching implications.

The evolutionary path of IoT has emerged as a result of several interrelated factors. Primarily, it reflects the natural progression of technological capabilities, from basic sensor

Theme	Subthemes	Current research status	Research gaps
Business Transformation	Servitization and Advanced Services; Innovation in Business Models; Sustainability and Circular Economy	Well-developed; focus on shift to service-based models and IoT-enabled business models	More research needed on long-term sustainability of IoT-based business models
Organizational and Technical Factors	Impacts and Capabilities of Organizations; Smart Manufacturing and Industry 4.0; Technical Architecture and Security	Advancing rapidly; emphasis on organizational changes and Industry 4.0 applications	Further research required on organizational readiness and change management
User-Centric Applications and Effects	Consumer Behavior and Intelligent Products; Enhancement of Customer/User Experience; Smart Monitoring and Applications	Growing focus; studies on user perceptions and IoT applications in various sectors	Need for more diverse sector studies beyond manufacturing and smart homes
Challenges and Emerging Technologies	Challenges in IoT Adoption; IoT and Emerging Technologies; Data Analytics and Insights	Active area of research; addressing adoption barriers and exploring synergies with AI, blockchain	More research needed on overcoming interoperability issues and standards development
Additional Themes	Collaboration among Stakeholders; Ethical Considerations	Emerging focus; relatively underrepresented	Urgent need for more research on ethical implications and collaborative IoT solution design

Table 3.
IoT research themes in business and management: status and gaps

Source(s): Table by authors

networks and RFID systems to complex, AI-driven ecosystems. This trajectory has been shaped by advances in complementary technologies such as cloud computing, big data analytics, and artificial intelligence, which have expanded the potential applications and value proposition of IoT. Concurrently, the evolution has been driven by changing market demands and societal needs. For instance, the shift towards Industry 4.0 and smart manufacturing in the 2011–2015 period was a response to increasing global competition and the need for greater operational efficiency. Similarly, the recent focus on sustainability and healthcare applications is a direct result of growing environmental concerns and the global health challenges highlighted by the COVID-19 pandemic.

The themes in IoT research are not isolated topics but rather form a complex, interconnected system. At the core, the Technology and Infrastructure theme serves as the foundation, enabling advancements in all other areas. It directly influences the Data and Analytics theme, as improved sensors and connectivity allow for more sophisticated data collection and analysis. This, in turn, feeds into the Business Models and Strategy theme, as new data-driven insights enable novel value propositions and revenue streams. The Customers and Markets theme is closely tied to both Business Models and Data and Analytics, as consumer behavior and market trends shape (and are shaped by) new IoT applications and the data they generate. The Organizations and Work theme intersects with all others, as IoT implementations require and drive changes in organizational structures, work processes, and skill requirements. Finally, the Sustainability and Environment theme has emerged as an overarching concern, influencing decisions and developments across all other themes.

We observe a predominantly technocentric perspective in existing literature, focused substantially on architectural configurations, communication mechanisms, data analytics, and security protocols. This is understandable given IoT's roots in engineering and computer science. However, a broader socio-technical view is imperative as IoT becomes entrenched in business strategy and daily life. Our findings already highlight growing scholarship at these intersections – whether industry applications, value creation dynamics, or user perceptions. But more interdisciplinary perspectives can enrich the management research on IoT, drawing theories and constructs from information science, marketing, organizational behavior, and beyond.

This interconnectedness highlights the need for a holistic approach to IoT research and implementation, recognizing that advancements or challenges in one area will inevitably impact others. For instance, the ongoing focus on security and privacy issues has become more complex as IoT systems have become more pervasive and interconnected, influencing developments across all themes from technology infrastructure to business models and consumer adoption.

Another significant takeaway is the relative underrepresentation of sustainability considerations, ethical implications, and policy discourse in the IoT literature thus far. These systemic issues pose risks such as e-waste, privacy violations, and digital inequity, requiring urgent attention. Research on responsible, ethical IoT that aligns economic goals and social welfare is vital. Integrative frameworks on IoT governance can guide technology regulation and industry self-regulation. This aligns with our observation of the Sustainability and Environment theme emerging as an overarching concern, influencing decisions and developments across all other themes.

While manufacturing and supply chain contexts dominate scholarship presently, the applicability of IoT in diverse sectors remains underexplored. Business scholars should probe emerging and hybrid use cases spanning media, retail, financial services, education, and more. Comparative research across contexts can reveal commonalities and idiosyncrasies around IoT integration, business model transformation, and value creation. This aligns with our understanding of the Business Models and Strategy theme and its interconnections with other themes like Customers and Markets and Organizations and Work.

We also observed limited scholarship on organizational capabilities and change management aspects of IoT adoption. Further research on managerial challenges, best practices, and contextual success factors can produce actionable frameworks for practitioners struggling with integration. IoT's long-term payoffs rely heavily on organizational readiness across skills, structure, and culture. This gap in the literature is particularly notable given the centrality of the Organizations and Work theme in our thematic analysis and its intersections with all other themes.

Qualitative, ethnographic, and critical research methodologies appear underutilized currently. These approaches could provide deeper insights into the socio-technical aspects of IoT adoption and use, particularly in understanding user perceptions, organizational culture shifts, and the broader societal implications of IoT. Qualitative case studies on IoT assimilation and business transformation in leading companies can yield contextualized insights for other adopters, contributing to both the Organizations and Work and Business Models and Strategy themes.

Bringing all these together, Figure 2 below depicts the evolutionary process of IoT, highlighting key themes and relationships with aspects of business management.

While the field of IoT research in business and management has shown remarkable growth and evolution, there remain significant opportunities for further development. The interconnected nature of IoT themes necessitates a holistic, interdisciplinary approach to research. Future studies should aim to address the identified gaps, particularly in sustainability, ethics, and organizational change management, while also exploring the applicability of IoT across diverse sectors. By doing so, researchers can contribute to a more

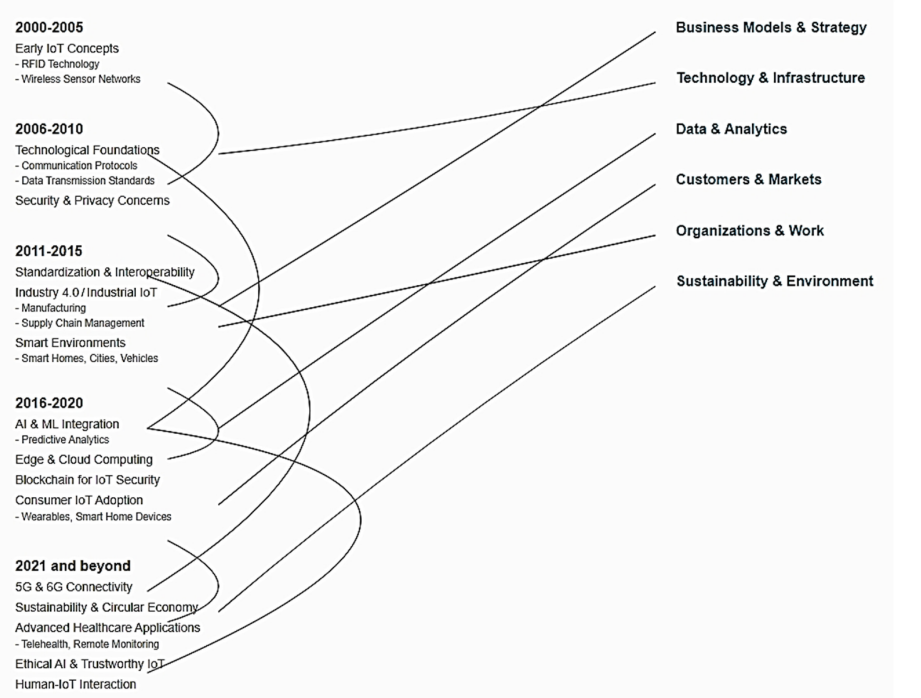


Figure 2.
The evolution of IoT and its interlacing with business management

Source(s): Figure by authors

comprehensive understanding of IoT's impact on business and society, guiding both scholarly discourse and practical implementation in this rapidly evolving field.

6. Conclusion

This literature review offers a comprehensive foundation and research agenda for management/business scholars pursuing research on the multifaceted phenomena of IoT. A combination of bibliometric analysis, temporal mapping, and thematic coding revealed both the current state and historical evolution of IoT research in this domain. Key observations indicate a burgeoning IoT literature focused predominantly on technological enablers, business applications, and consumer adoption. Information systems and technical disciplines still lead in volume output. However, growing attention to business model innovation, organizational change management and work practices signifies IoT's penetration into core management terrain.

Our findings synthesize existing knowledge on IoT while surfacing priority gaps where researchers can enrich understanding. We highlight promising opportunities around integration with emerging technologies like AI, advancing strategic thinking on risks and ethics, probing new use contexts beyond manufacturing, and developing practical toolkits for organizational IoT readiness. As digitalization, especially AI, fuels the scale and scope of connected device ecosystems, the need for management research to inform leadership around technology integration, workforce enablement and customer experience will be intensified.

We must acknowledge some key limitations of this study. Firstly, the focus on peer-reviewed articles published in business and management journals over the past decade, while systematic, excludes potentially a lot of significant contributions. Not all management of IoT related research might appear in management journals. IoT is one of those fields of inquiry where professional practice is significantly ahead of scholarly understanding of it. The reliance purely on academic literature may skew findings towards theoretical rather than applied perspectives. The screening process also inherently involved some subjectivity in assessing relevance. Moreover, while major themes were identified through inductive coding, some niche IoT topics may have been overlooked without an *a priori* framework. Furthermore, the quality appraisal of articles was limited without a formal critical analysis of study rigor of each work. The geographic variability of research was not expressly analyzed which leaves uncertainty regarding the transferability of findings across different countries and contexts. Finally, we must also be humble enough to accept that, as a rapidly advancing technology, the IoT landscape continues to fundamentally evolve which risks the generalizability of a historical review.

We are hopeful that our analysis will provide a launching pad for progressing management scholarship amidst IoT's expansive technological revolution. We offer a compass for researchers to orient future studies toward the most commercially and socially valuable directions. IoT's advancement from this point can be substantially shaped through evidence-based insights on harnessing its transformation power for operational sustainability, responsible innovation and human-centric prosperity. In this regard, the gaps in the literature that we identified could become the starting point of further empirical research.

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