

# Industry 4.0 Technologies in The Service Sector: A Systematic Literature Review

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## Abstract

**Purpose** – This study systematically reviews the literature on Industry 4.0 technology (I4T) adoption within the service sector—including Big Data analytics, Artificial Intelligence, and Robotics—to identify critical adoption trends, benefits, and challenges. Given the unique intangibility and heterogeneity of services, the research aims to outline a sector-specific roadmap for technological integration.

**Design/methodology/approach** – Following a dual-method approach, the study first employs bibliometric analysis to map the intellectual landscape of Industry 4.0 in services. This is followed by a Systematic Literature Review (SLR) of 49 empirical studies published between 2013 and 2023, indexed in major databases such as Scopus and Web of Science.

**Findings** – The analysis reveals a distinct phased adoption model in which “Base Technologies” (e.g., Cloud Computing and Big Data) serve as a prerequisite infrastructure for “Front-end Technologies” (e.g., Robotics and AI). While I4T significantly enhances operational and financial performance, its success is heavily moderated by human-centered factors. These include customer psychological acceptance of automated interactions, and employee digital literacy. The results suggest that service-sector adoption is less about technical capability and more about balancing technological readiness with human-centric integration.

**Originality/value** – This study extends established frameworks, specifically the Diffusion of Innovation (DOI) and the Technology-Organization-Environment (TOE) model, by integrating a human-centric dimension essential for service environments. It provides a theoretical perspective on the socio-technical barriers to digital transformation and highlights how the documented phased progression in literature reflects the maturation and increasing commercial availability of front-end technologies.

**Keywords:** Industry 4.0; service sector; technology adoption; human-centered; systematic literature review

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## 1. Introduction

Industry 4.0 transformed manufacturing through increased automation and data-driven processes (Ghobakhloo *et al.*, 2024), but the potential for Industry 4.0 Technologies (I4T) to reshape the service industry remains underdeveloped (Imran *et al.*, 2018), despite enhanced efficiency and customer experience personalization (Alva & Carceres, 2025; Gupta and Jauhar, 2023). I4T innovations such as Internet of Things (IoT), artificial intelligence (AI), and robotics offer service organizations the ability to drive business model transformations and improve overall performance (Afandy *et al.*, 2022; Ślusarczyk *et al.*, 2020). Nevertheless, service sector characteristics—primarily intangible output and reliance on human-centric information—pose challenges that require specialized strategies for I4T adoption (Chung and Kim, 2024).

Reviews identify several technological advancements that shape I4T adoption in service industries (Belk *et al.*, 2023; Moldabekova *et al.*, 2020; Rahman & Akhtar, 2025), but limited research examines the interplay between technological potential and sector-specific challenges (Mariani and Borghi, 2019), such as the need for significant organizational resources, strategic alignment, and adaptive capabilities

tailored to services. The extent of I4T’s influences on services has yet to be explored fully. Barriers such as high initial costs, skill shortages, and varying degrees of employee and customer receptivity (Aceto *et al.*, 2020; Matana *et al.*, 2020; Osei *et al.*, 2020) further complicate adoption. A nuanced, comprehensive review is thus needed to synthesize these barriers, anticipated outcomes, and adoption trends in this context.

A systematic literature review (SLR) provides insights into the trends, organizational outcomes, and barriers specific to services. Unlike extant reviews that identify emerging technologies and broad industry challenges, this SLR provides a sector-specific synthesis, drawing connections among organizational needs, resource dependencies, and adoption outcomes. We clarify the challenges service organizations experience and examine how sectoral characteristics influence I4T adoption, addressing three research questions:

RQ1: What trends affect I4T adoption in service industries?

RQ2: What outcomes are monitored to assess I4T adoption effectiveness in service industries?

RQ3: What barriers do organizations encounter during I4T adoption in service industries?

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## 2. Literature Review

Industry 4.0 builds on industrial revolution advancements to support or replace humans during decision-making (Xu *et al.*, 2018). Several I4T facilitate real-time collection and the exchange, analysis, and use of data (Haldorai, 2023). Such data improve customer service, optimize operations, develop new products, and help with decisions (Ziora, 2015). IoT connects a network of physical objects (Rahman *et al.*, 2022), AI allows machines to mimic human intelligence (Islam and Naseem, 2023), and ML is trained on data to make predictions (Sharma *et al.*, 2021). BDA extracts insights from large datasets using advanced statistical and ML (Filgueiras, de Melo, *et al.*, 2024), and cloud computing delivers computing services over the internet to provide on-demand computing resources (Chen *et al.*, 2022). CPS integrates physical devices with both hardware and software to create systems that are more responsive to sense, control, and interact with the physical world (Abdullah *et al.*, 2024), and robotics perform tasks automatically by following instruction sets (Moffitt *et al.*, 2018). Frank *et al.* (2019) classify I4T into two groups—base technologies, comprising cloud computing, IoT, and BDA, and front-end technologies, comprising AI and robotics.

This study explores the intersection of Industry 4.0 and services, including implications to service provision, organizational structures, and human engagement. Services comprise a substantial portion of modern economies (Mariani and Borghi, 2019), but as intangibles, they rely on customer interactions, personalization, and experiential value (Bettencourt and Gwinner, 1996). As I4T adoption accelerates across services, it is crucial to recognize that this transformation extends beyond implementation of digital tools. The combination of CPS and data-driven decision-making redefines how services are conceptualized, designed, and delivered (Feng *et al.*, 2020; Hamzah *et al.*, 2023). For example, IoT and interconnected systems allow creation of smart service ecosystems (Rejeb *et al.*, 2022), and service providers are increasingly using data analytics and ML, combined with AI, to personalize offerings, predict customer preferences, and optimize resource allocation (Haleem *et al.*, 2022). The convergence of new technologies in services suggests bridging the physical and the digital, fostering a new era of interconnectedness and intelligence (Hofmann *et al.*, 2019). Data privacy and security are paramount because organizations process vast amounts of customer information (Dilyard *et al.*, 2021; Lafuente, 2015). The shift toward automation raises questions about the future of human workers in service roles and the need for upskilling and reskilling (Zirar *et al.*, 2023), with some perspectives suggesting that human workers can collaborate symbiotically with technological advancements (Jarrahi, 2018). Integration of digital

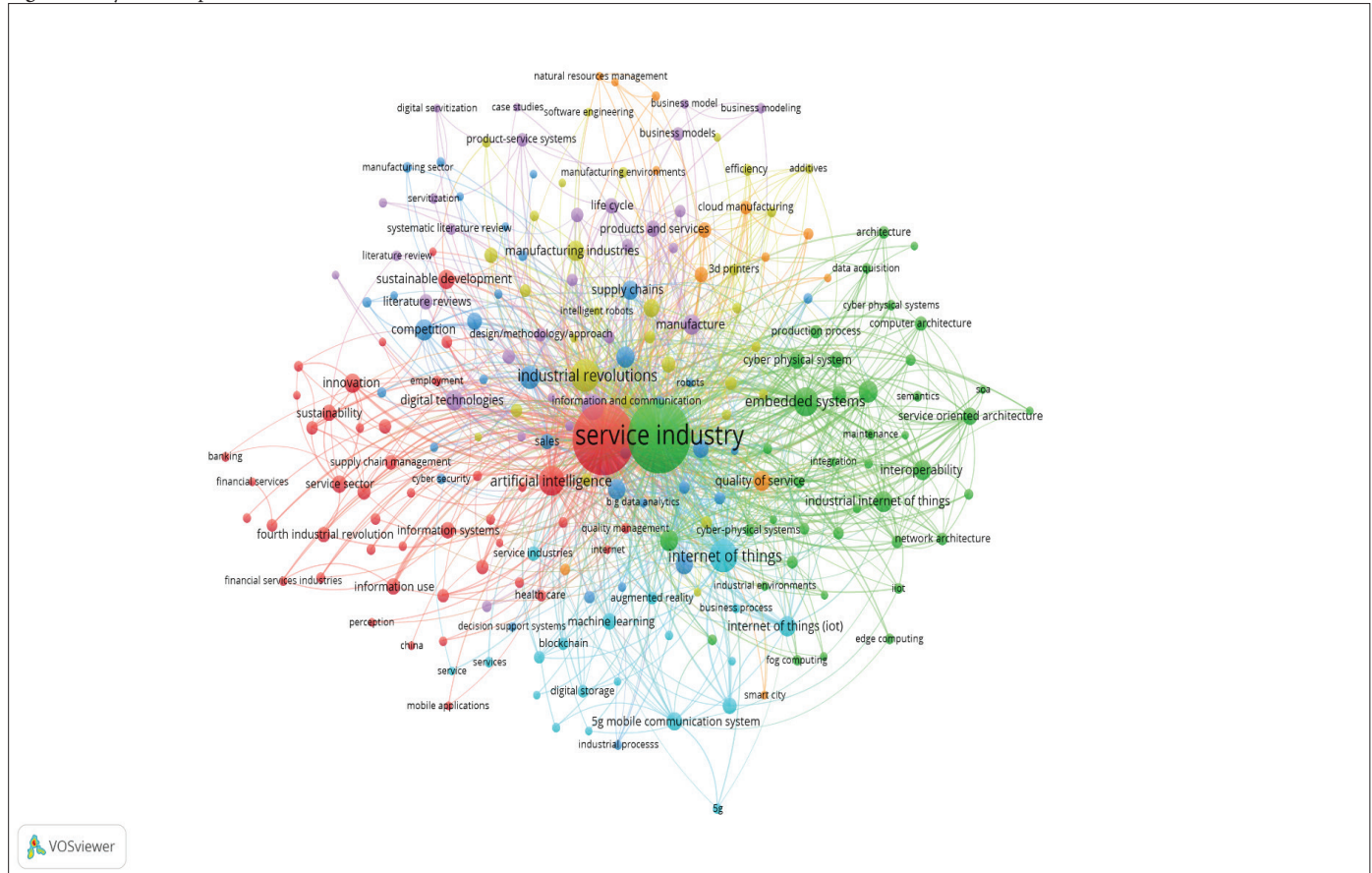
technologies leads to disruptions in traditional value chains, requiring service providers to adapt to remain competitive (Büyüközkan and Göçer, 2018), though disruptions also create opportunities (Müller *et al.*, 2018). The influences of these disruptions on employee outcomes (e.g., job satisfaction, work-life balance, and career development) represent a critical area of inquiry. We use bibliometric analysis to assess and map trends quantitatively, offering an overview of extant research, including gaps.

## 3. Preliminary Study: Bibliometric Analysis

Bibliometric analysis provided a systematic and objective approach to analyzing extant literature on Industry 4.0 and the service sector. By searching databases, we identify potential topics for further exploration. Bibliometric analysis consists of three steps—data collection, network visualization, and interpretation and analysis—which allow identification of themes, trends, and potential research directions. We searched Scopus using search terms INDUSTRY 4.0, FOURTH INDUSTRIAL REVOLUTION, I4.0, 4TH INDUSTRIAL REVOLUTION, SERVICE SECTOR\*, SERVICE INDUSTRY\*, and SERVICE FIRM\*, which yielded 575 papers. We processed this list using VOS Viewer software to generate a diagram (Figure 1) to identify themes. By analyzing cooccurrence patterns and semantic relationships between terms, we highlighted three clusters of keywords that collectively base the discussions on Industry 4.0 and the service sector—Industry 4.0 (blue), Study (red), and Practice (green).

The “Innovation & Digital Tech in Services” (red cluster) contains keywords such as “artificial intelligence, innovation, digital technologies, sustainability,” and “fourth industrial revolution,” implying a focus on digital transformation and the adoption of Industry 4.0 within service industries. The green cluster or Technical Integration and Systems, emphasizes literature on technical infrastructure, architecture, and systems enabling I4.0, comprising terms such as “embedded systems, cyber physical systems, interoperability, service oriented architecture”. The Reviews & Evaluation (blue cluster) focuses on a body of work doing meta-analysis or bibliometric review of I4.0 in services, represented by terms “systematic literature review, sustainable development, competition”. Keywords within the yellow cluster, Manufacturing-Service Nexus, such as “manufacturing industries, products and services, 3d printers, cloud manufacturing,” point towards a focus on the convergence of manufacturing and services, often referred to as servitization. The cyan cluster, Emerging Tech & Networks, highlights emerging technologies being investigated for future service applications. This cluster includes terms like “5g, blockchain, smart city, augmented reality, machine learning.”

Figure 1. Keyword Map



Notes: Blue = Reviews & Evaluation cluster; Red = Innovation & Digital Tech in Services cluster; Green = Technical Integration and Systems cluster; Yellow = Manufacturing-Service Nexus cluster; Cyan = Emerging Tech & Networks cluster

Source: Authors

High connectivity among the central keywords “service industry, artificial intelligence, internet of things,” reflect a shared foundation across diverse research strands and a substantial focus on synthesizing and applying I4T concepts to service contexts. The overlap between the Innovation & Digital Technologies in Services (red) and Technical Integration and Systems (green) clusters suggests a research trend toward aligning strategic innovation goals with practical technical implementations. This reflects an interdisciplinary turn in the literature—merging conceptual innovation strategies with system-level applications. The distribution of keywords across these five clusters reveals a field that is both multidimensional and highly interconnected, spanning strategic perspectives, infrastructure development, evaluation studies, service-manufacturing integration, and emerging technologies.

#### 4. Systematic Literature Review

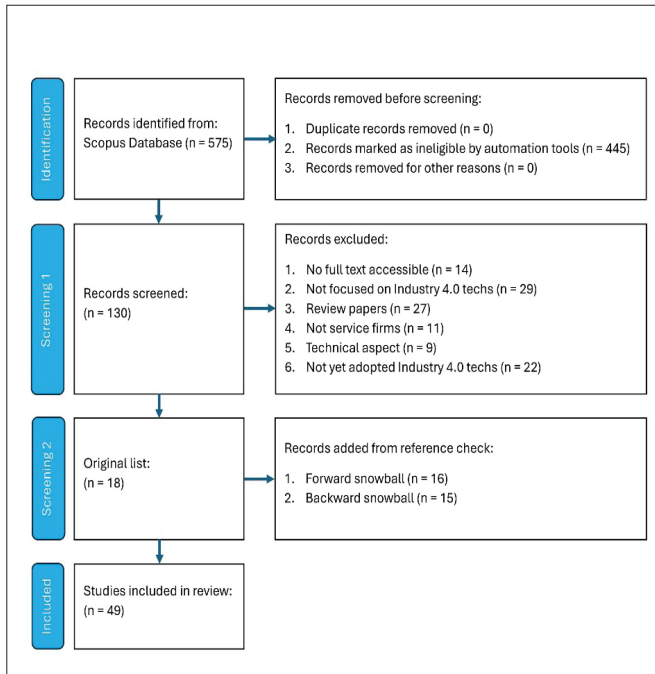
##### 4.1 Methods

We investigate academic publications using an SLR, a method that evaluates extant studies, synthesizes data, and identifies knowledge gaps (Denyer and Tranfield, 2009). Structured selection that included

relevant papers and excluded irrelevant ones ensured reliability and applicability, conducted using the PRISMA approach (Moher *et al.*, 2009), which ensures adherence to evidence-based reporting standards and critical appraisal. The process involves four steps (Figure 2). First is identification of relevant articles, followed by two screening steps and then use of the snowballing technique. The process results in a final list of articles for analysis.

We searched for Industry 4.0 terms using Mariani and Borghi’s (2019) and Sahoo *et al.*’s (2022) criteria, which included 4TH INDUSTRIAL REVOLUTION, INDUSTRY 4.0, FOURTH INDUSTRIAL REVOLUTION and I4.0 as keywords. These publications have a 3-year gap, demonstrating development of the 4th industrial revolution in terms of research. To accommodate broader results in service industries, keywords SERVICE SECTOR\*, SERVICE INDUSTRY\*, and SERVICE FIRM\* were used to search article titles, abstracts, and keywords in the Scopus database, resulting in 575 articles. We focused our initial search on the Scopus database due to its wider coverage of scholarly journals compared to other prominent databases like Web of Science (Singh *et al.*, 2021), ensuring a more comprehensive capture of relevant literature.

Figure 2. PRISMA Diagram



Source: Authors

Several criteria were used during the identification stage (Table 1). Papers must be written in English and only peer-reviewed journal articles were considered, which excluded non-refereed publications (Light and Pillemer, 1984). To ensure alignment with the research questions, a filter was applied to business, management, and economics subject areas to provide strong methodological consistency in the sample. The result was 130 papers eligible for screening.

The first and second authors conducted the first screening independently to select eligible papers, with disagreements resolved through discussions until consensus was reached. Data extracted from the papers were transferred to a spreadsheet, in which additional items were incorporated to streamline data management. The process began by assessing full-text availability of each paper and reviewing titles and abstracts to exclude those that did not align with the research scope. Papers that did not discuss I4T, discussed organizations that had not yet implemented I4T, or discussed only technical aspects of I4T, were removed. Theoretical reviews were excluded. One hundred two papers were ineligible, resulting in a final sample of 18 papers.

Table 1. Inclusion Criteria

Criteria	Details
Language	English
Document type	Articles and reviews
Subject area	Business, management, and accounting; decision sciences; economics and econometrics; finance; social sciences
Publication year	Fewer than 10 years old

Source: Authors

For the subsequent screening, we employed a snowball technique,

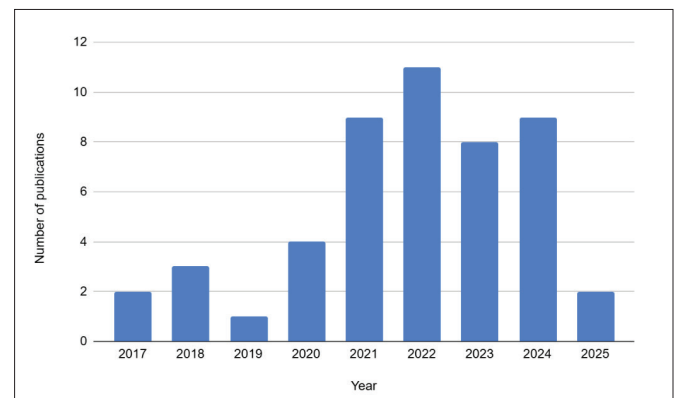
which was significantly facilitated by Scopus’s robust citation tracking features (Valente *et al.*, 2022). This hybrid approach, integrating the Scopus database search with both forward and backward snowballing, is recommended for strong systematic literature reviews, often yielding an optimal balance of precision and recall (Mourão *et al.*, 2020; Neto *et al.*, 2021; Wohlin *et al.*, 2022). Conducted by the first author and replicated by the second, the second screening explored papers using the snowball technique. For forward snowballing (Wohlin, 2014), we used Scopus’ “cited by [xx] documents” feature, which resulted in 15 articles. Backward snowballing involved examining the reference lists of the original papers to identify articles that met inclusion criteria, from which 16 articles were found. The authors reached consensus, and the final selection consisted of 49 articles.

## 4.2 Sample Descriptions

### 4.2.1 Number of Publications

By examining papers published on Industry 4.0 in service industries per year, preliminary mapping was used to gain broad understanding of the papers analyzed. Figure 3 shows a fluctuating pattern from 2017 to 2025, indicating varying degrees of research activity. Limited attention was paid to the topic during early years, but an increase is evident starting from 2020 to date. This trend highlights growing recognition of the significance of Industry 4.0 to services.

Figure 3. Number of Publications



Source: Authors

### 4.2.2 Countries Researched

Research on Industry 4.0 and service firms conducted in developed and developing countries is distributed equally. Asia comprises the most common countries of origins (Table 2), though some studies lacked geographic details, suggesting an even broader range of countries.

### 4.2.3 Service Sectors Researched

Research on Industry 4.0 and services reveals industries in which I4T adoption has been studied extensively (Table 2). Financial services, healthcare, and food services represent the industries most researched, followed by transportation & logistics, IT services, and tourism and hospitality, suggesting that I4T improves service delivery. To a lesser extent, other industries (e.g., healthcare and contact centers) have also been studied.

## 5. Results

### 5.1 I4T Adopted in Service Industries

Analysis of the sampled literature reveals an evolutionary pattern in scholarly attention to I4T within service industries, shifting from “base” to “front-end” technologies. While earlier studies predominantly examined non-industry-specific tools like BDA, publications since 2020 have increasingly focused on AI and robotics. This trend reflects a shift in research emphasis rather than a universal adoption

sequence. Instead, it mirrors the maturation and increasing commercial availability of front-end technologies. Early research naturally gravitated toward established digital infrastructures (Bhagat *et al.*, 2022; Wamba *et al.*, 2017), whereas the recent surge in customer-facing applications, such as robot baristas (Hwang *et al.*, 2024; Park *et al.*, 2023), aligns with the broader post-2020 proliferation of service robotics. Consequently, the literature captures a transition from back-end data management toward the complexities of the human-technology service interface.

**Table 2.** List of Publications

Authors	Countries	Developed	Developing	Financial services	Food services	Transportation & logistics	Tourism & hospitality	IT services	Healthcare	Other sectors
(Gunasekaran <i>et al.</i> , 2017)	India		✓					✓		
(Wamba <i>et al.</i> , 2017)	China		✓							not specified
(Cohen, 2018)	not specified			✓		✓	✓	✓		
(Dezi <i>et al.</i> , 2018)	Italy	✓		✓						
(Imran <i>et al.</i> , 2018)	Pakistan		✓			✓				
(Niebel <i>et al.</i> , 2019)	German	✓								not specified
(Ordieres-Meré <i>et al.</i> , 2020)	not specified					✓				
(Ślusarczyk <i>et al.</i> , 2020)	Hungary, Canada, Poland	✓				✓				
(Sung and Jeon, 2020)	South Korea	✓			✓					
(Yadav <i>et al.</i> , 2020)	India		✓							not specified
(Benzidia <i>et al.</i> , 2021)	France	✓							✓	
(Damoah <i>et al.</i> , 2021)	Ghana		✓						✓	
(Ghouri <i>et al.</i> , 2021)	Malaysia		✓		✓		✓			
(Hwang <i>et al.</i> , 2021a)	South Korea	✓			✓					
(Hwang <i>et al.</i> , 2021b)	South Korea	✓			✓					
(Kim <i>et al.</i> , 2021)	South Korea	✓			✓					
(Narayanamurthy and Tortorella, 2021)	India		✓	✓						
(Shamim <i>et al.</i> , 2021)	Pakistan		✓				✓			
(Sony <i>et al.</i> , 2021)	not specified									not specified
(Batko and Ślęzak, 2022)	Poland	✓							✓	
(Bhagat <i>et al.</i> , 2022)	India		✓	✓		✓	✓		✓	
(Chen <i>et al.</i> , 2022)	not specified									not specified
(Drydak, 2022)	England	✓								not specified
(Huang, 2022)	China		✓				✓			
(Kumar and Chakraborty, 2022)	India		✓						✓	
(Rahman <i>et al.</i> , 2022)	Canada & Bangladesh	✓	✓			✓				
(Sarbu, 2022)	German	✓						✓		
(Tortorella, Prashar, <i>et al.</i> , 2022)	India		✓							contact centers
(Tortorella, Fogliatto, <i>et al.</i> , 2022)	Brazil, India, Mexico, Argentina		✓						✓	
(Yuen <i>et al.</i> , 2022)	Singapore	✓						✓		
(Antony <i>et al.</i> , 2023)	not specified									not specified
(Chatterjee <i>et al.</i> , 2023)	not specified								✓	
(Santos <i>et al.</i> , 2023)	China-Pakistan		✓							law firm
(Islam and Naseem, 2023)	not specified							✓		
(Kim <i>et al.</i> , 2023)	South Korea	✓			✓					
(Park <i>et al.</i> , 2023)	South Korea	✓			✓					
(Tapia-Andino and Barcellos-Paula, 2023)	Canada	✓		✓						
(Zhong and Moon, 2023)	China		✓							not specified
(Abdullah <i>et al.</i> , 2024)	India		✓							not specified
(Filgueiras, de Melo, <i>et al.</i> , 2024)	Brazil		✓	✓						
(Filgueiras, Melo, <i>et al.</i> , 2024)	not specified			✓						
(Hassan <i>et al.</i> , 2024)	German	✓								not specified
(Hwang <i>et al.</i> , 2024)	South Korea	✓			✓					
(Jorge Ulises and Pablo José, 2024)	Peru		✓	✓						
(Kabel <i>et al.</i> , 2024)	Sweden	✓							✓	
(Sharma <i>et al.</i> , 2024)	India		✓	✓				✓		
(Zaid <i>et al.</i> , 2025)	Palestine		✓						✓	
(Bronzini <i>et al.</i> , 2025)	Italy	✓								not specified
(Wu and Zhu, 2025)	China		✓							not specified

Source: Authors

This nascent research documents that service firms typically adopt base technologies before moving to more advanced front-end applications, though they remain limited in the total number of I4Ts they can feasibly integrate. The most common base technology identified is BDA (Table 3). Effectiveness in BDA adoption depends on two primary pillars: infrastructure (Bhagat *et al.*, 2022; Bronzini *et al.*, 2025; Dezi *et al.*, 2018; Islam and Naseem, 2023; Rahman *et al.*, 2022), and management capabilities (Gunasekaran *et al.*, 2017; Shamim *et al.*, 2021) combined with personnel expertise (Bronzini *et al.*, 2025; Wamba *et al.*, 2017). To succeed, organizations must invest in hardware, software, and network capabilities while aligning BDA with business objectives. Furthermore, they must prioritize attracting and retaining talent skilled in data analytics, machine learning, and domain-specific knowledge.

Approximately one-third of the reviewed papers assess the adoption of front-end technologies such as AI, AR, and robotics. Research into robotics specifically emphasizes the food industry, particularly coffee shops (Ghouri *et al.*, 2021; Hwang *et al.*, 2021b, 2021a, 2024; Kim *et al.*, 2023, 2021; Park *et al.*, 2023; Sung and Jeon, 2020). This topic gained prominence during the COVID-19 pandemic, as robot baristas were deployed to facilitate social distancing. Enhancing robotics adoption in this context requires a focus on management and brand experience. Coffee shops should define specific roles for robots to optimize service and avoid human redundancy, while training employees to complement robotic capabilities. Finally, firms must acknowledge that while robots offer efficiency, they currently lack the emotional connection and behavioral engagement provided by human baristas.

**Table 3.** I4T Adopted and Outcomes Reported

Authors	I4T: Base	I4T: Front-End	Outcomes Level: Not Specified	Outcomes Level: Organization	Outcomes Level: Employee	Outcomes Level: Consumer
(Gunasekaran <i>et al.</i> , 2017)	✓			✓		
(Wamba <i>et al.</i> , 2017)	✓			✓		
(Cohen, 2018)	✓			✓		
(Dezi <i>et al.</i> , 2018)	✓			✓		
(Imran <i>et al.</i> , 2018)	✓			✓		
(Niebel <i>et al.</i> , 2019)	✓			✓		
(Ordieres-Meré <i>et al.</i> , 2020)	✓			✓		
(Ślusarczyk <i>et al.</i> , 2020)			✓	✓		
(Sung and Jeon, 2020)		✓				✓
(Yadav <i>et al.</i> , 2020)	✓	✓		✓	✓	
(Benzidia <i>et al.</i> , 2021)	✓	✓		✓		
(Damoah <i>et al.</i> , 2021)		✓		✓		
(Ghouri <i>et al.</i> , 2021)	✓					✓
(Hwang <i>et al.</i> , 2021a)		✓				✓
(Hwang <i>et al.</i> , 2021b)		✓				✓
(Kim <i>et al.</i> , 2021)		✓				✓
(Narayanamurthy and Tortorella, 2021)	✓				✓	
(Shamim <i>et al.</i> , 2021)	✓					✓
(Sony <i>et al.</i> , 2021)	✓			✓		✓
(Batko and Ślęzak, 2022)	✓	✓		✓		
(Bhagat <i>et al.</i> , 2022)	✓			✓		
(Chen <i>et al.</i> , 2022)	✓			✓		
(Drydakis, 2022)		✓		✓		✓
(Huang, 2022)		✓				✓
(Kumar and Chakraborty, 2022)	✓	✓		✓		
(Rahman <i>et al.</i> , 2022)	✓			✓		
(Sarbu, 2022)	✓			✓		
(Tortorella, Prashar, <i>et al.</i> , 2022)	✓				✓	
(Tortorella, Fogliatto, <i>et al.</i> , 2022)	✓	✓		✓		
(Yuen <i>et al.</i> , 2022)		✓				✓
(Antony <i>et al.</i> , 2023)			✓	✓		
(Chatterjee <i>et al.</i> , 2023)	✓	✓		✓		
(Santos <i>et al.</i> , 2023)			✓	✓		
(Islam and Naseem, 2023)	✓	✓		✓		
(Kim <i>et al.</i> , 2023)		✓				✓
(Park <i>et al.</i> , 2023)		✓				✓
(Tapia-Andino and Barcellos-Paula, 2023)			✓		✓	
(Zhong and Moon, 2023)			✓	✓		
(Abdullah <i>et al.</i> , 2024)	✓	✓		✓		
(Filgueiras, de Melo, <i>et al.</i> , 2024)	✓	✓		✓		
(Filgueiras, Melo, <i>et al.</i> , 2024)			✓	✓		
(Hassan <i>et al.</i> , 2024)			✓	✓		
(Hwang <i>et al.</i> , 2024)		✓				✓
(Jorge Ulises and Pablo José, 2024)	✓			✓		
(Kabel <i>et al.</i> , 2024)	✓	✓		✓		
(Sharma <i>et al.</i> , 2024)	✓	✓		✓		
(Zaid <i>et al.</i> , 2025)	✓	✓		✓		
(Bronzini <i>et al.</i> , 2025)	✓	✓		✓		
(Wu and Zhu, 2025)		✓		✓	✓	

Source: Authors

## 5.2 Outcomes of I4T

Research on I4T in service industries emphasizes organizational-level outcomes, such as performance (Table 3), with sales growth, market share, and return on investment as common measures. Findings suggest that I4T influences organizational performance positively; for instance, Wamba *et al.* (2017) documented an 8% increase in revenue and 47% lower customer acquisition costs, while Chen *et al.* (2022) reported a 1.6–1.7% increase in Return on Assets (ROA). Beyond operational gains, Bronzini *et al.* (2025) found that I4T adoption significantly improves financial health by lowering the cost of debt and reducing credit rationing. However, a shift in organizational-level outcomes was also evident, especially sustainability (Filgueiras, de Melo, *et al.*, 2024; Filgueiras, Melo, *et al.*, 2024; Ordieres-Meré *et al.*, 2020; Santos *et al.*, 2023; Zaid *et al.*, 2025), with three aspects most prominent—environmental, social, and economic. From an environmental perspective, I4T promotes paperless offices through remote work, and from a social one, it allows employees to focus on more fulfilling work, which improves work-life balance by reducing routine tasks. From an economic perspective, I4T contributes to broader growth; for example, while systemic inefficiencies can account for 20–30% of total healthcare expenditures (Tortorella, Fogliatto, *et al.*, 2022), I4T implementations have achieved specific offsets such as 10–15% reductions in inventory waste (Damoah *et al.*, 2021) and revenue savings of up to 4.5% (Yadav *et al.*, 2020).

Individual-level outcomes were few but fell into two groups—performance (Narayanamurthy and Tortorella, 2021) and experience (e.g., satisfaction and frustrations) (Tortorella, Prashar, *et al.*, 2022; Yadav *et al.*, 2020). Productivity outcomes are particularly pronounced in data-driven environments, where Niebel *et al.* (2019) observed a 5–6% productivity boost. Benefits include streamlined processes, fewer errors, and better decisions through real-time data and analytics. I4T automates repetitive and physically demanding tasks, reducing physical strain, and it improves flexibility regarding work hours and location, which results in improved job satisfaction and work-life balance. Batko and Ślęzak (2022) found that these operational improvements led to 76.5% of facilities achieving a measurable

ROI in their settlement processes. However, challenges to I4T adoption include employee resistance and difficulties with maintaining social connections and a sense of belonging.

Evident is a rise in the number of publications on customer perspectives (Ghouri *et al.*, 2021; Huang, 2022; Hwang *et al.*, 2021a, 2021b, 2024; Kim *et al.*, 2021; Park *et al.*, 2023; Shamim *et al.*, 2021; Sony *et al.*, 2021), such as customer acceptance (Sung and Jeon, 2020; Yuen *et al.*, 2022) and customers' intentions to use I4T (Kim *et al.*, 2023). I4T enhance customer satisfaction through faster service, improved accuracy, and personalized experiences. Furthermore, it improves accessibility for guests with disabilities, making services more inclusive. A shift from organizational to individual foci is evident, offering more comprehensive understanding of Industry 4.0's broader societal and human implications, beyond organizational performance.

## 5.3 Barriers to I4T Adoption in Service Industries

I4T adoption in service industries experiences many barriers, which we identify as either internal and external (Table 4), a grouping that helps organizations understand the causes of barriers so that they can allocate resources toward targeted solutions. External barriers derive from outside the organization, consisting of regulatory and legal (Abdullah *et al.*, 2024; Benzidia *et al.*, 2021; Dezi *et al.*, 2018), economic (Antony *et al.*, 2023; Drydakis, 2022; Tortorella, Fogliatto, *et al.*, 2022; Zaid *et al.*, 2025), technological (Batko and Ślęzak, 2022; Islam and Naseem, 2023; Shamim *et al.*, 2021; Sony *et al.*, 2021; Zaid *et al.*, 2025), and human factors (Batko and Ślęzak, 2022; Filgueiras, Melo, *et al.*, 2024; Islam and Naseem, 2023; Kabel *et al.*, 2024; Shamim *et al.*, 2021; Sony *et al.*, 2021; Sung and Jeon, 2020; Yuen *et al.*, 2022). Regulatory discontinuities and data privacy concerns create legal hurdles. The high cost of adoption, large investments required, and uncertainty about future profitability represent economic barriers. Insufficient IT infrastructure, lack of digital infrastructure, and shortages of qualified personnel are technological barriers. Lack of available talent, IT professionals' perceptions, and consumer trust and security concerns are human factors. Customers' perceived risks also hinder I4T adoption.

Table 4. Barriers to I4T Adoption

Authors	External: Regulatory and Legal	External: Human Factors	External: Economic	External: Technological	Internal: (Individual Level) Skills and Expertise Gaps	Internal: (Organizational Level) Resource and Capability Limitations	Internal: (Organizational Level) Technological and Infrastructural Deficiencies	Internal: (Organizational Level) Organizational Culture and Change Management Issues	Internal: (Organizational Level) Financial and Strategic Concerns
(Cohen, 2018)						✓		✓	
(Dezi et al., 2018)	✓				✓				
(Niebel et al., 2019)							✓		
(Sung and Jeon, 2020)		✓							
(Benzidia et al., 2021)	✓						✓		
(Shamim et al., 2021)		✓		✓					
(Sony et al., 2021)		✓		✓	✓			✓	
(Baiko and Sığzak, 2022)		✓		✓	✓		✓		✓
(Drydaki, 2022)			✓			✓		✓	
(Huang, 2022)								✓	✓
(Kumar and Chakraborty, 2022)						✓			
(Tortorella, Prashar, et al., 2022)					✓		✓		✓
(Tortorella, Fogliatto, et al., 2022)			✓						
(Yuen et al., 2022)		✓							
(Antony et al., 2023)			✓						
(Chatterjee et al., 2023)					✓		✓	✓	
(Islam and Nascem, 2023)		✓		✓	✓		✓	✓	
(Zhong and Moon, 2023)						✓		✓	
(Abdullah et al., 2024)	✓					✓			
(Figueiras, Melo, et al., 2024)		✓						✓	
(Jorge Ulises and Pablo José, 2024)					✓				✓
(Kabel et al., 2024)		✓							✓
(Zaid et al., 2025)			✓	✓	✓			✓	

Source: Authors

Internal barriers derive from inside the organization, divided into two levels—organizational and individual. Internal organizational barriers arise from Resource and Capability Limitations (Abdullah *et al.*, 2024; Cohen, 2018; Drydakakis, 2022; Jorge Ulises and Pablo José, 2024; Kumar and Chakraborty, 2022; Zhong and Moon, 2023), Technological and Infrastructural Deficiencies (Batko and Ślęzak, 2022; Benzidia *et al.*, 2021; Chatterjee *et al.*, 2023; Islam and Naseem, 2023; Niebel *et al.*, 2019; Tortorella, Prashar, *et al.*, 2022), Organizational Culture and Change Management Issues (Chatterjee *et al.*, 2023; Cohen, 2018; Drydakakis, 2022; Filgueiras, Melo, *et al.*, 2024; Huang, 2022; Islam and Naseem, 2023; Sony *et al.*, 2021; Zaid *et al.*, 2025; Zhong and Moon, 2023), as well as Financial and Strategic Concerns (Batko and Ślęzak, 2022; Huang, 2022; Jorge Ulises and Pablo José, 2024; Kabel *et al.*, 2024; Tortorella, Prashar, *et al.*, 2022). Organizational Culture and Change Management Issues were the most significant, reflecting the need for organization-wide initiatives to ensure the smooth adoption of I4T. At the individual level, barriers derive from employees' lack of skills and expertise in technology (Batko and Ślęzak, 2022; Chatterjee *et al.*, 2023; Dezi *et al.*, 2018; Islam and Naseem, 2023; Jorge Ulises and Pablo José, 2024; Sony *et al.*, 2021; Tortorella, Prashar, *et al.*, 2022; Zaid *et al.*, 2025), suggesting that human factors are the most important in the adoption of new technologies.

## 6. Discussion

### 6.1 Theoretical Implications

#### 6.1.1 Phased Adoption of I4T in Service Industries

Our finding of a reported phased adoption of I4T in service industries—progressing from “base technologies” like BDA and Cloud to “front-end technologies” like AI and robotics—aligns with the Diffusion of Innovations (DOI) theory's concept of gradual adoption (Rogers, 1995). While this documented sequence in the literature is partially a byproduct of the historical maturation and recent commercial availability of front-end hardware, our analysis suggests that the progression also reflects deeper service-specific strategic necessities including structural data maturity, risk mitigation, and human-centered integration. Theoretically, front-end innovations are data-consumptive, requiring the foundational digital plumbing of integrated architectures to ensure technical compatibility (Malacaria *et al.*, 2023; Yan & Jones, 2025). Furthermore, by adopting scalable Software as a Service (SaaS) models first, firms may increase financial trialability, using early operational efficiencies to fund the high capital expenditure of physical front-end hardware (Tashkandi & Al-Jabri, 2015; Putrevu & Mertzanis, 2024). This stagewise approach (Saghafian *et al.*, 2021) facilitates organizational learning, allowing employees to develop digital literacy in back-end environments before managing technologies that directly impact the customer experience. Consequently, this sequence appears as a strategic mechanism to build absorptive capacity and codify tacit knowledge (Cepa, 2021), ensuring that human and technical infrastructures are mature enough to prevent innovation rejection. However, the pace of this progression remains moderated by industry-specific risk profiles and human-centric barriers.

#### 6.1.2 Balancing Individual and Organizational Dimensions

Limited research at the individual level highlights the importance of balancing both organizational and individual dimensions in service firms, with holistic understanding of Industry 4.0's effects being essential. This finding supports E. Kim *et al.*'s (2022) suggestion that technology adoption should focus not only on benefits, but human aspects such as digital literacy, innovative work behaviors (Elisabeth *et al.*, 2023), safety (Arana-Landín *et al.*, 2023), job quality, and worker wellbeing (Meylemans *et al.*, 2021). Under-researched perspectives of technology adoption include individual wellbeing, motivation, and satisfaction. Theories such as self-determination theory (SDT; Deci & Ryan, 2000) and the job-demands-resources (JD-R) model (Bakker and Demerouti, 2017) address these dimensions. By considering users' psychological needs and motivations, technology aligns with these factors, increasing adoption and sustained use (Chiu, 2022).

#### 6.1.3 Reframing the TOE Framework for Service Industries

Building on the barriers identified in Section 5.3, this study argues that the TOE framework (Tornatzky *et al.*, 1990) must be refined to account for the unique characteristics of the service sector. The regulatory, economic, technological, and human barriers observed across service industries reveal that technology adoption is shaped not only by structural conditions, but also by service risk profiles and interaction intensity. Specifically, the findings suggest that the “Environmental” and “Organizational” contexts of the traditional framework are heavily moderated by a service's risk profile and interaction intensity. In high-risk, regulated sectors like healthcare (Zaid *et al.*, 2025), the environmental context is dominated by stringent regulatory compliance and data privacy concerns, where high failure costs lead to a cautious prioritization of “base technologies”, such as Cloud and Big Data, to ensure reliability before pursuing full-scale automation (Batko and Ślęzak, 2022). Conversely, in low-risk, high-interaction services like retail or hospitality, the organizational context shifts toward agility and customer experience. In these environments, lower failure costs allow for the rapid adoption of front-end technologies, with customer psychological acceptance serving as the primary moderator for success (Yuen *et al.*, 2022).

To accommodate these dynamics, we propose expanding the TOE model to better reflect the “human-centered” nature of service delivery. While extant research typically assesses external barriers through the lens of technological constraints from providers (Rahman *et al.*, 2022), our results highlight customer acceptance as a challenge unique to services. This suggests that the Technology Acceptance Model (TAM; Davis, 1989) should be integrated into the external “Environmental” dimension of TOE to account for consumer trust and perceived risks during the adoption process. By incorporating TAM, the framework moves beyond technical infrastructure to include the social-psychological barriers that define service-based interactions.

Furthermore, we deepen the “Organizational” dimension by introducing change resistance as a critical internal barrier. While traditional models focus on organizational resources and processes (Rahman *et al.*, 2022), we argue that organizational culture (Abu Bakar *et al.*,

2024) and strong leadership (Wahab *et al.*, 2025) are essential moderators that can mitigate resistance to I4T. At the individual level, the findings offer insights into employee resistance driven by perceived complexity and fear of job displacement. This necessitates the inclusion of an “Individual” dimension within the TOE framework to emphasize talent management, specifically through investments in reskilling and upskilling to increase technology adaptability (Hendrikx and Stoffers, 2022, 2023; Stoffers *et al.*, 2021). Ultimately, these refinements underscore the coevolution of technology adoption and human capital development, providing a more nuanced roadmap for I4T implementation in diverse service contexts.

## 6.2 Research Agendas

Future research should address global variations during adoption, refine theoretical frameworks to accommodate services, and explore interplays between the individual and organizations. Long-term effects of I4T adoption on services remain underexplored. By addressing these topics, research contributes to advancement of theory in the field, and provides practical guidance for service organizations that are navigating increasingly complex, competitive environments.

### A. Global Variations During Technology Adoption

Exploration of global variations in I4T adoption should be expanded to be country-specific, identifying factors, such as economic conditions, government policies, cultural attitudes, and the presence of early-adopters (Kim *et al.*, 2025), that influence adoption and strategies. Doing so will allow multinational companies and policymakers to address national contexts’ specific needs.

### B. Refining Technology Adoption Frameworks for Services

Extant technology adoption frameworks should be refined because service delivery, centered on human interactions, requires adapted models (Jeilani and Hussein, 2025; Madaki *et al.*, 2025). By examining customer-facing employees and personalized service, future research will contribute to tailored trajectories of I4T adoption.

### C. Individual and Organizational Dimensions

Research should explore the balance between individual and organizational dimensions in the context of Industry 4.0 (Granić, 2024), investigating how technology adoption influences human skills, digital literacy, and workforce development. Practical guidance from such research would help organizations adopt holistic approaches during technology adoption.

### D. Long-Term Effects of I4T Adoption on Services

Longitudinal studies that track the evolution of I4T adoption across multiple industries are critical to understanding trends (Bai *et al.*, 2022). Such research should analyze how adoption patterns, strategies, and outcomes change in response to technology, offering insights into the long-term implications of Industry 4.0 for economic development and competitiveness, and providing guidance for organizations to maintain and improve competitive advantages.

## 6.3 Limitations

Using a single database for article selection might have excluded relevant research and thus influenced the review’s comprehensiveness. Bias from extant literature’s diverse terms that describe I4T represents a limitation, and varied terminology might have resulted in exclusion of articles. Publication bias is inherent to SLRs because they assess only published literature. Numerous studies on Industry 4.0 exist but were never published, and thus their findings cannot be analyzed. This study’s inclusion of only English-language articles introduced a language bias, ignoring non-English research and influencing representativeness. Geographic scope was also a challenge, with broad terms such as *continents* used instead of individual countries, leading to inconsistencies when categorizing articles by location and thereby affecting precision. Concentration on service industries represents a limitation to the generalizability of findings to other sectors.

## 6.4 Practical Implications

This study provides practical guidance to service firms that are considering I4T adoption. A key takeaway for practitioners is that I4T is not merely a technological upgrade but a verified driver of financial health, as adoption has been shown to significantly lower the cost of debt and reduce credit rationing (Bronzini *et al.*, 2025). The findings suggest a clear business case for investment: foundational “base” technologies offer immediate wins by reducing inventory waste (Damoah *et al.*, 2021) and generating revenue savings (Yadav *et al.*, 2020), while “front-end” innovations significantly lower customer acquisition costs (Wamba *et al.*, 2017). By framing I4T as a strategic path to improved ROA (Chen *et al.*, 2022) and higher productivity (Niebel *et al.*, 2019), managers can better justify the necessary capital expenditure to stakeholders.

Given the sector’s reliance on human capital and personalized interactions, a balanced approach is needed. Strategies include phased adoption, prioritizing employee needs among technological goals, and addressing internal and external barriers. By adopting a human-centered approach and iterative progress monitoring, service firms optimize I4T adoption outcomes, ensuring personalized customer service.

I4T adoption requires a balance between technological goals and employee needs. Organizations must invest in digital literacy to upskill employees and ensure their wellbeing. Fostering an innovative culture encourages employee engagement with I4T, and addressing concerns about job changes and providing reassurance through reskilling mitigate employees’ fears and ensure smooth transitions. Service organizations must overcome both external and internal barriers to adopt I4T, and thus proactive strategies are needed to address regulatory, economic, and technological constraints. Engaging in industry-wide discussions shapes favorable regulatory environments, and internally, a clear, leader-backed vision for I4T adoption is essential. Cultivating a culture of innovation and continuous learning, led by champions of technological change, facilitates smooth transitions.

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