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Industrial Revolution 4.0 technologies for democratic e-government services: A systematic review of transformational frameworks

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Abstract: This paper uses the PRISMA framework to present a systematic literature review on e-government frameworks leveraging Fourth Industrial Revolution technologies. It aims to identify, review, and analyze frameworks that incorporate emerging technologies like artificial intelligence, machine learning, algorithms, natural language processing, big data analytics, blockchain, Internet of Things, cloud computing, cognitive computing, and autonomous robots to modernize public administration service delivery. The review covers articles from 2019 to 2024, highlighting the potential of Fourth Industrial Revolution technologies to enhance government services, improve accountability, and foster citizen engagement. However, it also identifies gaps in current frameworks, such as challenges related to security, privacy, and the digital divide. The paper provides recommendations for developing transformational e-government frameworks that prioritize democratic values, social inclusion, and stakeholder participation.

Keywords: e-government frameworks, Fourth Industrial Revolution (IR 4.0), systematic literature review, emerging technologies, public administration transformation

1. Introduction

The world is experiencing a significant evolution driven by the rapid advancement of new and emerging technologies, transforming economies and shaping future generations (WEF, 2023). As a result, various sectors, including private companies, agencies, and governments worldwide, are increasingly integrating digital solutions and recognizing the importance of leveraging Fourth Industrial Revolution (IR 4.0) technologies such as the Internet of Things (IoT), robotics, and artificial intelligence in e-government services (United Nations, 2022). IR 4.0 allows governments to modernize public administration, enhance accountability, promote transparency and citizen engagement (Kornyshova & Barrios, 2020), and promote efficiency, enhanced transparency, and security in e-government processes (Mustafa et al., 2024). Furthermore, emerging technologies have significant transformation capabilities of e-government infrastructures, from their early theoretical foundations to their current advanced applications in areas such as machine learning, predictive analytics, and natural language processing with large language models (Yun et al., 2024). IR 4.0 marks the current phase of sector digitization, characterized by disruptive trends like blockchain, cloud computing, big data analytics, and advancements in robotics and human-machine interaction (McKinsey, 2022). This revolution necessitates a fundamental shift in how we work, live, and interact (Mazur, 2022; WEF, 2018).

E-government is the robust integration of information and communication technologies (ICT) in daily operations to improve efficiency and transparency while serving individuals, citizens, and businesses (Rijarua & Osakwe, 2023). The growth of e-government initiatives in developing and transitioning countries is hindered by issues such as poor digital infrastructure, digital divide, lack of standard policies, legal frameworks, and fragmented e-government solutions (Namagembe et al., 2023). These countries also face slow progress in implementing and adopting e-government approaches (Adrees et al. 2019).

In the context of e-government frameworks, there have been efforts to incorporate several IR 4.0 technologies into the studies. This review focuses on e-government frameworks and their leverage of IR 4.0 technologies. The review aims to synthesize and analyze existing literature to identify significant e-government frameworks. The findings of this review are intended to inform e-government practitioners, agencies, policymakers, and researchers by providing a comprehensive overview of the current state of knowledge regarding e-government framework design and the integration of IR 4.0 technologies. Further studies should focus on designing a comprehensive transformational e-government framework leveraging IR 4.0 technologies based on gaps identified in existing frameworks.

This study aims to conduct a comprehensive review and analysis of existing literature on e-government frameworks, focusing on their utilization of IR 4.0 technologies. To achieve this objective, the following research questions were formulated:

RQ1: What are the characteristics of the reviewed studies in terms of theoretical foundations, methodologies used, and geographical areas?

RQ2: How have existing studies leveraged IR 4.0 technologies in the design of e-government frameworks?

RQ3: What are the components, strengths, weaknesses, and gaps in the existing e-government frameworks?

This study contributes to the academic literature by providing a comprehensive review of the impact of IR 4.0 technologies on democratic e-government services. It also identifies key transformational frameworks and assesses their effectiveness in enhancing democratic processes. The findings of this study can guide policymakers and regulatory bodies in formulating policies that utilize IR 4.0 technologies to improve the efficiency, transparency, and accessibility of e-government services. Additionally, it emphasizes the need for regulatory standards and guidelines to ensure ethical considerations and data security in implementing IR 4.0 technologies in public administration. Ultimately, this study lays the foundation for future research that should propose a practical framework to guide the implementation of IR 4.0 technologies in e-government services, assisting government agencies in the process of democratic e-government transformation.

The remainder of the paper is structured as follows. The next section provides a review of the literature on the impact of IR 4.0 technologies on e-government and the challenges faced by developing countries in adopting these technologies. The third section outlines the methodological approach, including the narrative review process and the application of the PRISMA framework for systematic review. The fourth section presents the classification framework used for analyzing the data, which includes the features of the reviewed e-government frameworks, the incorporation of IR 4.0 technologies, and the components, strengths, weaknesses, and gaps of these frameworks. The fifth section discusses the findings, addressing the research questions and highlighting the gap in the comprehensive incorporation of IR 4.0 technologies in e-government frameworks. The final section presents the conclusion, areas for further research, and limitations of the study.

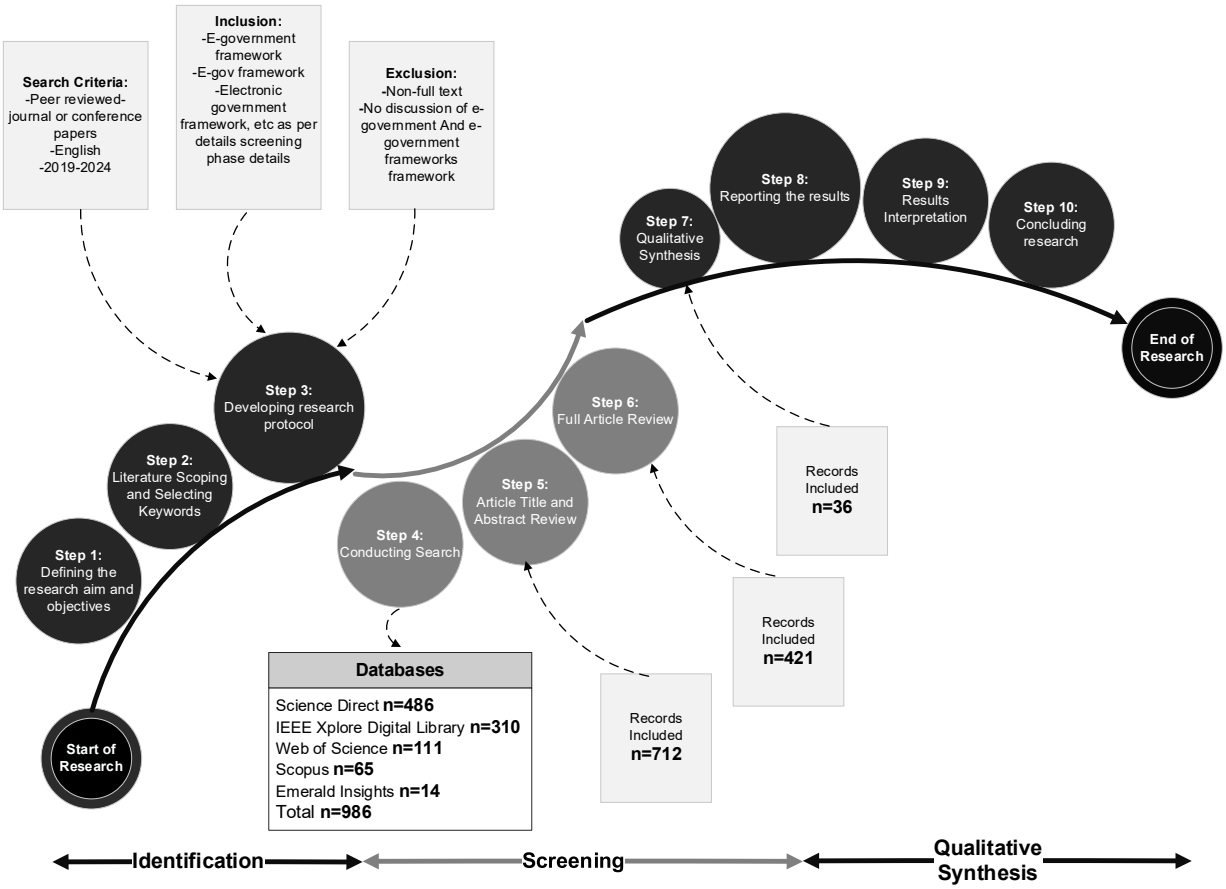
2. Research Methodology

To enhance the rigor, transparency, and comprehensiveness of the review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework was employed to structure the methodology and presentation of findings (Frost et al., 2022; Page et al., 2021; Booth et al., 2020). Traditionally associated with systematic reviews, the PRISMA framework was used in this study to systematically categorize, select, evaluate, and synthesize studies, thereby providing a clear and detailed account of the review process and its outcomes.

The review was conducted in three phases following the PRISMA framework: 1) identification, which involved literature sensitization, keyword selection, and the development of a research protocol for search criteria and inclusion/exclusion criteria; 2) screening, which entailed searching, reviewing titles and abstracts, and assessing full-text articles; and 3) qualitative synthesis, where the

screened results were analyzed, synthesized, and reported. Figure 1 illustrates the systematic review process for selecting and evaluating e-government frameworks using the PRISMA framework.

Figure 1: PRISMA flow diagram: illustrating the systematic review process for selecting and evaluating studies on e-government frameworks[1]



This structured approach ensured alignment with the study's nature, purpose, and objectives, as guided by the recommendations of Booth et al. (2020). The subsequent sections of the paper delve into each of these phases in detail.

2.1. The Search Identification Phase

Seven keyword strings were employed across five databases to conduct the literature search: Scopus, ScienceDirect, Web of Science, IEEE Xplore Digital Library, and Emerald Insight. These keywords encompassed terms such as "e-government framework," "e-gov framework," "electronic government framework", "smart government“, "digital government“, "public administration“, "IR 4.0 technologies”, “e-government 4.0", "IR 4.0", "emerging technologies", "artificial intelligence", "machine learning", "deep learning", "neural networks", "natural language processing", "computer

[1] As conducted by the authors of the review paper

vision", "image recognition", "intelligent systems", "virtual assistant", "predictive analytics", "automation", and "robotics". The search strategy combined these keyword strings, as outlined in Table 1, and was restricted to peer-reviewed journal articles and conference papers published from 2019-2024 and only in English.

Table 1: Search queries and criteria applied in different databases for the literature review on e-government frameworks

Database	Advanced Search Query/Criteria
Scopus	(TITLE-ABS-KEY("e-government frameworks" OR "e-gov frameworks" OR "electronic government frameworks" OR "e-government" OR "smart government" OR "digital government" OR "public administration")) AND (TITLE-ABS-KEY("IR 4.0 technologies" OR "IR 4.0" OR "emerging technologies" OR "artificial intelligence" OR "machine learning" OR "deep learning" OR "neural networks" OR "natural language processing" OR "computer vision" OR "image recognition" OR "intelligent systems" OR "virtual assistant" OR "predictive analytics" OR "automation" OR "robotics"))
ScienceDirect	("e-government frameworks" OR "e-gov frameworks" OR "electronic government frameworks" OR "e-government" OR "smart government" OR "digital government" OR "public administration") AND ("IR 4.0 technologies" OR "IR 4.0" OR "emerging technologies" OR "artificial intelligence" OR "machine learning" OR "deep learning" OR "neural networks" OR "natural language processing" OR "computer vision" OR "image recognition" OR "intelligent systems" OR "virtual assistant" OR "predictive analytics" OR "automation" OR "robotics")
Web of Science	(TS=("e-government frameworks" OR "e-gov frameworks" OR "electronic government frameworks" OR "e-government" OR "smart government" OR "digital government" OR "public administration")) AND (TS=("IR 4.0 technologies" OR "IR 4.0" OR "emerging technologies" OR "artificial intelligence" OR "machine learning" OR "deep learning" OR "neural networks" OR "natural language processing" OR "computer vision" OR "image recognition" OR "intelligent systems" OR "virtual assistant" OR "predictive analytics" OR "automation" OR "robotics"))
IEEE Xplore Digital Library	("All Metadata": "e-government frameworks" OR "All Metadata": "e-gov frameworks" OR "All Metadata": "electronic government frameworks" OR "All Metadata": "e-government" OR "All Metadata": "smart government" OR "All Metadata": "digital government" OR "All Metadata": "public administration") AND ("All Metadata": "IR 4.0 technologies" OR "All Metadata": "IR 4.0" OR "All Metadata": "emerging technologies" OR "All Metadata": "artificial intelligence" OR "All Metadata": "machine learning" OR "All Metadata": "deep learning" OR "All Metadata": "neural networks" OR "All Metadata": "natural language processing" OR "All Metadata": "computer vision" OR "All Metadata": "image recognition" OR "All Metadata": "intelligent systems" OR "All Metadata": "virtual assistant" OR "All Metadata": "predictive analytics" OR "All Metadata": "automation" OR "All Metadata": "robotics")
Emerald Insights	"e-government frameworks" OR "e-gov frameworks" OR "electronic government frameworks" OR "e-government" OR "smart government" OR "digital government" OR "public administration"

Database	Advanced Search Query/Criteria
	AND ("IR 4.0 technologies" OR "IR 4.0" OR "emerging technologies" OR "artificial intelligence" OR "machine learning" OR "deep learning" OR "neural networks" OR "natural language processing" OR "computer vision" OR "image recognition" OR "intelligent systems" OR "virtual assistant" OR "predictive analytics" OR "automation" OR "robotics")"

The search process also included forward and backward citation screening in Web of Science and IEEE Xplore Digital Library. Some databases like ScienceDirect require a maximum of eight boolean characters. Therefore, character selection was randomly reduced to meet the search attempts. The Zotero tool was utilized to organize the selected bibliographic data and associated research materials, such as PDF files.

2.2. The Screening Phase

The primary screening method involved using keywords, titles, and a brief analysis of abstracts. Key terms defined in the search identification phase were utilized to explore peer-reviewed literature. Articles that did not focus on the e-government framework and IR 4.0 technologies were excluded, along with conference abstracts, encyclopedias, magazines, book chapters, and other irrelevant materials. The search was limited to publications from 2019 to 2024, and only those with full text available were considered.

As demonstrated in Figure 1, a total of 986 publications were initially identified following the search protocol. After removing duplicates and reviewing titles and abstracts, the pool was reduced to 712 publications. Further scrutiny resulted in 421 papers being selected for full-text review. Ultimately, after a comprehensive evaluation, 36 papers were included in the qualitative synthesis of the study.

2.3. The Qualitative Synthesis Phase

This study employed thematic synthesis, a method developed by Thomas and Harden (2008), which combines elements from meta-ethnography and grounded theory to enhance the clarity and flow of the review. This approach was chosen to address questions related to the need for appropriateness, acceptability, and effectiveness of interventions or transformations in the context of e-government frameworks (Barnett-Page & Thomas, 2009). The synthesis aimed to maintain the core principles of systematic reviews while providing a comprehensive literature analysis.

The review process involved evaluating the selected studies based on several criteria, including the authors, publication year, geographical areas covered, methodologies used, and the strengths, weaknesses, and identified gaps in the research. A particular focus was placed on the components forming the e-government frameworks and how they incorporated IR 4.0 technologies such as AI, machine learning, algorithms, natural language processing, big data analytics, blockchain, IoT, cloud computing, augmented reality, autonomous robots, etc.

Each publication was coded to examine the inclusion of IR 4.0 technologies in e-government frameworks. Coding involved systematically categorizing and labeling key information from each publication. The extracted data on IR 4.0 technologies leveraged in the reviewed e-government frameworks provided insights into the current state of technology integration in this field. This process was iteratively applied to new sets of papers, with reflectivity checks conducted to ensure the accuracy and reliability of the findings.

3. Review Findings

3.1. Overview of Selected Studies on Recent E-Government Frameworks

The final selection of studies for review comprised 36 papers, as detailed in Table 2. These studies spanned five years (from 2019 to 2024). This timeframe was chosen because it encompassed recent advancements and developments in e-government frameworks and emerging IR 4.0 technologies. Given the rapid pace of technological evolution, studies from this period were more likely to offer insights into current trends, challenges, and solutions related to the implementation and transformation of e-government systems. Furthermore, these publications were expected to employ contemporary methodologies and reflect up-to-date practices in the development and deployment of e-government frameworks, thereby ensuring that the review captured the most recent research approaches and strategies. Additionally, research conducted during this timeframe was anticipated to incorporate emerging technologies increasingly integrated into e-government frameworks, to enhance efficiency, transparency, and service delivery.

Table 2: An overview of key characteristics of the reviewed e-government frameworks

Features of Reviewed E-government Framework Papers	
Category	**Details**
Total Reviewed Studies	n=36
Year of Publication	2019 (n=4) 2020 (n=4) 2021 (n=4) 2022 (n=5) 2023 (n=16) 2024 (n=3)
Geographical Areas of Study	Afghanistan (n=1) Azerbaijan (n=1) [with Saudi Arabia] Brazil (n=1) China (n=4) Czech Republic (n=1) France (n=1) [with France, China, and Brazil] Germany (n=1) Ghana (n=1) Greece (n=2) India (n=3) [with Norway, South Africa, UK, Saudi Arabia, and Malaysia] Indonesia (n=2) [with the United Kingdom] Iran (n=1) [with the United Kingdom and Lithuania] Lebanon (n=1) [with Qatar, United Kingdom, and Turkey] Malaysia (n=2)

Features of Reviewed E-government Framework Papers	
Category	**Details**
	Morocco (n=1) Namibia (n=1) Nigeria (n=1) [with the UK] Pakistan (n=1) Saudi Arabia (n=1) South Africa (n=2) Tanzania (n=1) Thailand (n=2) Turkey (n=2) Uganda (n=1) [with Austria and Netherlands] United Kingdom (n=1) [with China, Thailand, and Tanzania]
Research Methods	Qualitative research (n=14) Quantitative research (n=9) Mixed methods (n=6) Undefined/unexplicit (n=7)
Data Collection Instruments	Case studies and literature reviews (n=12) Data generated from smart city environments (n=1) Exploratory surveys (n=1) Interviews (n=3) Mixed techniques (combination of questionnaires, interviews, and observations) (n=7) Modeling (n=3) Questionnaires (n=4) Simulation (n=1) Undefined/unexplicit (n=5)
Theories/Models Employed	Cognitive analytics management (CAM) (Osman et al., 2019) Data envelopment analysis (DEA) (Osman et al., 2019) Social cognitive theory (SCT) (Osman et al., 2019) Cognitive mapping theory (CMT) (Osman et al., 2019) Modification of the diffusion of innovation (DOI) theory (Apleni & Smuts, 2020) E-government requirements engineering process model (EGREPM) (Nyansiro et al., 2021) E-government viewpoints model (EGVM) (Nyansiro et al., 2021) E-government goals model (EGM) (Nyansiro et al., 2021) Multi-criteria decision-making (MCDM) method (Shayganmehr et al., 2022) E-government enterprise architecture framework (EGEAF) (Namagembe et al., 2023) Architecture development method of the Open Group architecture framework (TOGAF ADM) (Namagembe et al., 2023) Design science research model (DSRM) (Lnenicka & Komarkova, 2019; Namagembe et al., 2023; Rijarua & Osakwe, 2023; Sadat & Saadat, 2023) The Delone and McLean information systems success model (Rijarua & Osakwe, 2023) Organizational information processing theory (Rijarua and Osakwe, 2023) Deep reinforcement learning (DRL) model (Malik et al., 2023) Optimal blockchain leveraging approach (Malik et al., 2023) Deep learning (DL) model (Prasad and Reddemma, 2022; Raja et al., 2023) Convolutional neural networks (CNN) (Raja et al., 2023)
Academic Journals	Complex Systems Informatics and Modeling Quarterly (n=1) East African Journal of Science, Technology and Innovation (n=1) Emerald Publishing (n=1) European Journal of Operational Research (n=1)

Features of Reviewed E-government Framework Papers	
Category	**Details**
	Government Information Quarterly 41 (n=1) IEEE Access (n=3) i-manager's Journal on Image Processing (n=1) Information Technology & People (n=1) Information Technology for Development (n=1) International Journal of Advanced Computer Science and Applications (n=1) International Journal of Artificial Intelligence and Machine Learning (n=1) International Journal of Engineering Technology and Management Sciences (n=1) International Journal of Information Management (n=1) International Journal of Information Systems and Social Change (IJISSC) (n=1) International Journal of Law and Management (n=1) International Journal of Science and Research Archive (n=1) Journal of Information Systems and Informatics (n=1) Journal of Natural Science Review (n=1) Journal of Urban Management (n=1) Responsible Design, Implementation, and Use of Information and Communication Technology (n=1) Taylor and Francis Group (n=1) Technological Forecasting and Social Change (n=1) Telecommunications Policy (n=1) 2019 Open Innovations (OI) (n=1)
Conference Proceedings[2]	2022 19th International Joint Conference on Computer Science and Software Engineering (JCSSE) (n=1) 2022 IEEE International Conference on Computing (ICOCO) (n=1) 2022 International Conference on Artificial Intelligence of Things (ICAIoT) (n=1) 2023 International Scientific Conference of Engineering Sciences (ISCES-2023) (n=1) 2023 IEEE 17th International Conference on Application of Information and Communication Technologies (AICT) (n=1) 2023 IEEE International Conference on Cryptography, Informatics, and Cybersecurity (ICoCICs) (n=1) 2023 3rd International Conference on Digital Society and Intelligent Systems (DSInS) (n=1) E3S Web of Conferences (n=1) International Conferences e-Society 2023 and Mobile Learning (n=1) The International Conference on Education, Social, Sciences and Technology (ICESST) (n=1)

The geographical scope of the reviewed papers included low-income developing countries (Afghanistan, Azerbaijan, Ghana, Indonesia, Iran, Lebanon, Malaysia, Morocco, Namibia, Pakistan, Tanzania, Thailand, Turkey and Uganda), emerging market economies (Brazil, China, India, Nigeria, Saudi Arabia and South Africa) as well as advanced economies (Czech Republic, France, Germany, Greece, and the United Kingdom). The categorization into low-income developing countries, emerging market economies, and advanced economies was guided by country classification by the International Monetary Fund (IMF, 2023).

The reviewed studies predominantly utilized qualitative research methods, with 14 studies employing this approach. Quantitative research methods were used in nine studies. Mixed methods

[2] For each conference one publication was selected for inclusion in the final review.

were adopted in six studies. Lastly, seven studies did not explicitly state employed research methods.

In the reviewed studies, various methods were employed to collect data. Twelve publications used case studies and literature reviews, one study generated data from the smart city environments, and one implemented exploratory surveys. Furthermore, three studies conducted interviews, seven employed mixed techniques (combining questionnaires, interviews, and observations), and three modeled data. Additionally, four studies utilized questionnaires, one used simulated data, and five did not explicitly define data collection methods.

The identified theories, models, and frameworks are considered in detail in the subsequent subsection 3.2.

3.2. E-government Frameworks: Components, Strengths, Weaknesses, and Gaps

The reviewed studies encompass a wide range of foundational theories, frameworks, and models pertinent to technology adoption, particularly in e-government implementation. However, some studies incorporated IR 4.0 technologies in their framework design to guide the e-government transformation, and others did not consider incorporating IR 4.0 technologies. Additionally, the review encompasses frameworks designed to guide specific e-government projects, incorporating both framework designs. While these frameworks are instrumental in their respective implementations, their applicability is often limited and not extensively tested across diverse contexts. Furthermore, the studies delve into conceptual frameworks aimed at enhancing the understanding of e-government implementations by elucidating the relationships between various concepts.

Subsections 3.2.1-3.2.4 provide a summary of 36 publications within the various contexts of this study: (1) frameworks for overcoming the digital divide, (2) studies exploring the use of IR 4.0 technologies in e-government, but not proposing any frameworks or models, (3) e-government frameworks not leveraging any IR 4.0 technologies, but where these technologies can be potentially integrated, (4) e-government frameworks leveraging IR 4.0 technologies (the main focus of this review), and (5) ethical issues in e-government related to the use of IR 4.0 technologies. The reviewed studies detail their components, strengths, weaknesses, and the gaps identified within them.

3.2.1. Frameworks For Overcoming The Digital Divide

Yun et al. (2024) defined the digital divide as a double disparity in physical access. The focus was on those who either "have" or "have not" in terms of ownership or physical access to the internet, digital devices, broadband, and other computing technology. Adeleye et al. (2024) defined the digital digital divide as “the haves and have-nots” and emphasized the need to endorse equitable access to technological resources.

The digital divide is a significant obstacle to society's ability to benefit from technological advancements in the digital age (Chen et al., 2023). Further, bridging this divide requires not only the development of the basic digital infrastructure but also the improvement of citizens' digital

literacy. Chen et al. (2023) further emphasized that to ensure that eliminating old inequalities does not create new ones, it is crucial to conduct a comprehensive assessment of digital literacy across different societal groups. By understanding the specific weaknesses of these groups, relevant policies and laws can be formulated to promote digital inclusion and achieve sustainable development goals. Djuric (2024) emphasized that developing countries face challenges in bridging the digital divide, providing adequate services, and ensuring access for all, which in turn affects the acceptance of e-government and further stated the criticality of security and privacy features in the digital divide context, as any deficiencies can impact user motivation.

The existing studies did not extensively investigate the topic of e-government frameworks and the digital divide; rather, these studies focused on the digital divide under different contexts like education, health, and the generic discussion of the digital divide and its inclusion. However, some studies highlighted the significance of implementing e-government in developing countries and emphasized the need for clear regulations and top-level support to bridge the digital gap between urban and rural areas (Alfiani et al., 2024). The research by Mesa (2023) underscores the role of education in influencing citizens' utilization of digital public services. Education and cultural dimensions play a crucial role in mitigating the digital divide and promoting digital citizenship rights (Mesa, 2023). Moreover, the studies investigate ICT disparities and digital divides within the context of emerging technologies. It also reveals that factors such as the human development index and research and development expenditure significantly shape the adopting of new technologies in the public sector (Lnenicka & Komarkova, 2019).

Table 3 summarizes the frameworks aiming at overcoming the digital divide, specifically in relation to e-government.

Table 3: Summary of the frameworks for overcoming the digital divide

S/N	Framework	Main Features	Strengths	Weaknesses	Identified Gaps
1.	A theoretical framework for evaluation of ICT disparities and digital divide in e-government (Lnenicka & Komarkova, 2019)	1. Traditional approach (ICT legal, institutional regime, ICT skills and education, ICT access and infrastructure, ICT use and online services) 2. New approach (emerging infrastructure and innovation, big and open linked data and engagement, sustainability and quality of life) 3. Explanatory factors (data analysis, validation)	Utilization of empirical strategies such as correlation, factor, regression, and cluster analyses that strengthen the empirical foundation of the study.	The framework focuses specifically on the EU member states for the exploratory analysis, which may limit the generalizability of the findings to a broader global context.	There is no focus on specific determinants of ICT disparities and digital divides in the context of new emerging IR 4.0 technologies.
2.	An inclusive digital	1. Interdisciplinarity	The framework proposes a	The framework strongly	No inclusion of any IR 4.0 digital

S/N	Framework	Main Features	Strengths	Weaknesses	Identified Gaps
	democracy conceptual framework for digital citizen participation (Fegert, 2023)	2. Technological innovativeness 3. Inclusivity	conceptual approach to digital participation platforms.	emphasizes inclusivity and overlooks other aspects of digital citizen participation.	technologies and how they can be leveraged for enhanced inclusivity.
3.	A transitional framework for analyzing the role of ICT in bridging the digital divide (Hussain et al., 2023)	1. Demographic indicators 2. Educational indicators 3. Economic indicators 4. Innovation indicators 5. Institutional indicators	The analysis is all-inclusive as it examines the digital divide from various ICT dimensions.	The framework focuses on China, making the digital divide findings less applicable to other countries' contexts.	The framework does not consider IR 4.0 technologies and how they can be leveraged to bridge the digital divide.
4.	A comprehensive framework for mitigating digital divide factors in higher education (Sadat & Sadaat, 2023)	1. Technical training and skills enhancement 2. Awareness and mentality preparation 3. ICT usage in teaching and learning 4. Reformation of the educational system based on ICT	The framework provided a solution to bridge the digital divide for enhanced educational outcomes.	The framework for digital divide mitigation is focused on the context of one university in Afghanistan.	Inconsistent power supply and Internet access were acknowledged but not fully addressed within the proposed framework.
5.	Educational technology and the digital divide: a conceptual framework for technical literacy inclusion (Adeleye et al., 2024)	1. Enhancement of access to technology 2. Development of digital literacy skills 3. Fostering a culture of inclusion within educational institutions	The framework highlights the importance of fostering a culture of inclusion within the educational setup.	The framework lacks empirical validation through fieldwork testing.	The framework is focused only on the digital divide in educational technology and is not elaborate.

3.2.2. Studies Exploring The Use of IR 4.0 Technologies In E-government

E-government projects aim to enhance the efficiency, transparency, and accessibility of governmental services by utilizing emerging technologies. The incorporation of IR 4.0 technologies presents novel prospects. Through the extensive literature search and review, we have explored the utilization of various IR 4.0 technologies in the context of e-government. The studies presented in this subsection explored the use of IR 4.0 technologies in e-government but did not result in any frameworks or models. The research by Mohammadabbasi et al. (2022) highlights the challenges encountered in implementing e-government systems, including legal uncertainties, uneven distribution, and limited functionality, particularly at the government level. The studies by Abdullah et al. (2022), Al Qudah et al. (2023), and Papadopoulou et al. (2020) underline the significance of establishing robust legal and regulatory frameworks, enhancing IT education,

developing adequate infrastructure, and fostering a receptive mindset among government officials towards disruptive IR 4.0 technologies and innovative practices. These studies also discuss the necessity of aligning digital resources with foreign policy objectives and providing comprehensive training to personnel to maximize the advantages of digital diplomacy, particularly in developing countries such as Indonesia. A summary of studies exploring the use of IR 4.0 technologies in e-government is provided in Table 4.

Table 4: Summary of studies exploring the use of IR 4.0 technologies in e-government

S/N	Topic	IR 4.0 Technologies Explored	Summary of Content	Weaknesses	Identified Gaps
1.	Applications and challenges of the Internet of Things in e-government (Papadopoulou et al., 2020)	Internet of Things	The paper discusses various applications of the Internet of Things in e-government.	The study does not discuss ethical and privacy concerns related to the use of IoT (specifically, sensors or communication channels).	The paper focuses only on one IR 4.0 technology applicability in e-government. It does not provide guidance on how IoT can be implemented within specific or general contexts.
2.	Blockchain technologies in e-government services (Abdullah et al., 2022)	Blockchain	The paper reviews the application of blockchain technology in enhancing e-government services.	Blockchain applicability in e-government transformation is not discussed in enough detail.	The paper focuses only on one IR 4.0 technology. It does not provide guidelines on implementing blockchain within specific or general contexts.
3.	Applications and consequences of using the Internet of Things in the smart government (Mohammadabbasi et al., 2022)	Internet of Things	The paper provides various applications and indicators of IoT use in e-government.	The paper does not include any specific case studies or real-world examples to illustrate the practical implications of the identified indicators.	The paper focuses only on one IR 4.0 technology. It does not provide guidance on how IoT can be implemented within specific or general contexts.
4.	A blockchain-based secure mutual authentication system for e-government services (Al-Ameri and Ayvaz, 2023)	Blockchain technology, including RSA cryptosystem, hash, SHA-265, secure authentication, asymmetric encryption,	The paper discusses a system that enhances security for e-government services through blockchain technology.	The paper does not discuss the potential challenges and ethical considerations that may arise while implementing the	The paper focuses only on one IR 4.0 technology. It does not provide guidelines on implementing blockchain within

S/N	Topic	IR 4.0 Technologies Explored	Summary of Content	Weaknesses	Identified Gaps
		digital authentication, distributed ledger		proposed blockchain-based authentication.	specific or general contexts.
5.	Application of artificial intelligence for iris recognition in e-government services (Al Qudah et al., 2023)	Artificial intelligence (deep learning and convolutional neural networks)	The paper discusses implementing biometric features (iris recognition) in e-government services.	Ethical and security aspects of the extraction of iris images are not discussed.	The paper focuses only on two IR 4.0 technologies (both within artificial intelligence). It does not provide guidance on how these technologies can be implemented within specific or general contexts.
6.	E-government in the era of IR 4.0 (Chandra and Firdausy, 2023)	IR 4.0 technologies in general (no specific technology)	The paper discusses the transformation of e-government in the era of IR 4.0.	The study might have limited applicability as research was conducted in the Indonesian context.	No specific IR 4.0 technologies and their applicability in e-government are discussed.
7.	An e-government system based on blockchain (Guo et al., 2023)	Blockchain	The study demonstrates the potential of blockchain in e-government information sharing and collaboration.	Challenges and optimization of blockchain technology for complex government environments are not discussed.	The study discusses using blockchain technology to improve security and reliability in e-government. It does not consider other IR 4.0 technologies or areas of application.

Table 4 summarizes seven studies that explored the use of IR 4.0 in e-government but did not propose any frameworks or models. Six studies explored only one IR 4.0 technology in different e-government dimensions implementation. One study discussed the use of IR 4.0 technologies in general but did not consider the applicability of any specific IR 4.0 technology in e-government. It can be concluded that although the reviewed studies focused on specific IR 4.0 technologies like IoT, blockchain, automation robotics, and artificial intelligence, none of these studies resulted in a framework that could guide the implementation of IR 4.0 technologies in e-government. This analysis underscores the need for further research to develop more integrated, scalable, and adaptable e-government solutions, contributing to the evolving discourse in public administration technology.

3.2.3. E-government Frameworks Not Leveraging IR 4.0 Technologies

E-government frameworks have undergone significant evolution over the years, primarily focusing on enhancing public service delivery, transparency and democracy, and efficiency in public administration. However, it is worth noting that some frameworks do not even consider the cutting-edge technologies associated with IR 4.0. These frameworks prioritize several aspects, such as user satisfaction, user-friendliness, infrastructure, relevance, security, user trust, transparency, website maturity, operational efficiency empowerment, service quality, customer orientation, channel orientation, information quality, and technology orientation. The study reviewed and analyzed 12 frameworks that did not leverage any IR 4.0 technologies but where those technologies can be potentially integrated. Table 5 summarizes these frameworks. The common gap identified in all these frameworks is the lack of integration of IR 4.0 technologies.

Table 5: Summary of e-government frameworks (not leveraging any IR 4.0 technologies)

S/N	Framework	Main Components	Strengths	Weaknesses	Identified Gaps
1.	A framework for digital government services' sustainability in the Gauteng provincial government, South Africa (Masemola et al., 2019)	1. Governance (sustainability of ICT projects, monitoring and evaluation of ICT projects) 2. Organizational and managerial elements (stakeholder management, government's silo operations) 3. Citizen factors (user trust, language, electronic participation)	Clear research paradigm behind the framework using interpretivism.	The framework is limited to the South African context (one province only) The paper uses ambiguous terms.	The research lacks an examination of specific IR 4.0 technologies.
2.	A cognitive analytics management framework for the transformation of electronic government, Turkey (Osman et al., 2019)	1. Cognition process 2. Analytics process 3. Management process	Holistic integration of cognitive, analytics, and management processes.	The complexity of the framework; reliance on the Likert scale for testing.	The framework does not address specific IR 4.0 technologies.
3.	An e-government framework for assessing readiness for public sector e-procurement in a lower-middle income country, Ghana (Adjei-	1. Online services 2. Telecommunication infrastructure 3. Human capital for ICT	Framework for assessing e-procurement readiness, empirically grounded.	Single-country focus; elite interviews may introduce biases.	The framework lacks integration of IR 4.0 technologies.

S/N	Framework	Main Components	Strengths	Weaknesses	Identified Gaps
	Bamfo et al., 2020)				
4.	An e-government implementation framework for a developing country, South Africa (Apleni and Smuts, 2020)	1. Critical success factors 2. Innovation-decision process based on the DOI theory	The framework provides detailed guidelines for e-government in developing contexts.	The complexity of the framework; cultural and political factors might impact implementation but are not considered.	The research does not explore any IR 4.0 technologies.
5.	Future of e-government: an integrated conceptual framework, India (Malodia et al., 2021)	1. Empowered citizenship 2. Hyper-integrated network 3. Evolutionary system architecture 4. Antecedents of e-government (citizen/ customer orientation, channel orientation, technology orientation) 5. Outcomes of e-government 6. Moderating values	Holistic integration of multiple stakeholder views.	The framework is limited to the Indian context.	The framework lacks integration of IR 4.0 technologies.
6.	A goal-oriented requirements engineering framework for e-government information systems (Nyansiro et al., 2021)	1. Viewpoints model 2. Goals model 3. E-government requirements engineering model	Structured approach focusing on goal elicitation.	The framework does not address scalability.	The framework does not incorporate any IR 4.0 technologies.
7.	A framework for identifying the factors affecting the use of e-government services, Greece (Ferelis et al., 2022)	1. Trust in e-government services 2. Trust in public administration (government) 3. Trust in the Internet 4. Trust in other people 5. Availability of resources 6. Computer self-efficacy 7. Perceived information 8. Perceived quality of services 9. Perceived ease of use 10. Perceived compatibility 11. Perceived operational benefits 12. Peer pressure	Comprehensive approach to technology adoption.	The framework is built based on Greek data; the complexity of the framework challenges the practical implementation.	The framework does not integrate any IR 4.0 technologies.

S/N	Framework	Main Components	Strengths	Weaknesses	Identified Gaps
		13. Perceived risk of personal data loss			
8.	A framework for assessing trust in e-government services under uncertain environment, Iran (Shayganmehr et al., 2022)	1. Usability 2. Trust in government 3. Citizen's social characteristics 4. Security 5. Privacy 6. Information quality 7. Service quality 8. Maintenance and support 9. Website design	The framework focuses on trust, security, and privacy.	The framework is limited to the Iranian context.	The framework does not leverage any IR 4.0 technologies.
9.	An ontology-based framework enabling semantic interoperability in Bhutan's e-government (Tshering and Anutariya, 2022)	1. Data layer 2. Domain ontology layer 3. Service and sharing layer	The paper proposed an ontology-based framework for e-government to support semantic interoperability.	The research is limited to Bhutan and may not be generalizable to other contexts.	No specific IR 4.0 technologies are discussed.
10.	An e-government enterprise architecture framework for developing economies (Namagembe et al., 2023)	1. Method view (steps and activities, comprehensive question log, expected outputs) 2. Product view (e-government products, synthesis and orchestration)	The architecture is designed for interoperability in developing economies.	The complexity of the architecture and significant resource requirements might challenge the practical implementation.	The architecture does not integrate any IR 4.0 technologies.
11.	A digital forensic readiness (DFR) framework for e-government (Nugroho et al., 2023)	1. Identification of DFR parameters 2. Mapping of DFR parameters 3. Use-case implementation 4. Policy content mapping 5. Determining policy articles 6. Policy design 7. Validating the results	The framework focuses on digital forensic readiness.	The framework lacks comprehensive validation and does not address scalability.	The framework does not integrate any IR 4.0 technologies.
12.	A framework for an integrated e-government system for public service sectors in developing countries using Design Science	1. Business process reengineering 2. ICT infrastructure 3. Security 4. Secure data exchange platform 5. Service integration 6. Online e-government services	An integrated approach focusing on security and interoperability.	The complexity of the framework and significant resource requirements might challenge the practical implementation.	The research does not explore any IR 4.0 technologies.

S/N	Framework	Main Components	Strengths	Weaknesses	Identified Gaps
	Research Methodology, Namibia (Rijarua & Osakwe, 2023)	7. Training			

Table 5 summarizes 12 frameworks that did not explore the use of IR 4.0 in e-government but where these technologies can be potentially integrated. It can be concluded that these studies focused only on designing e-government frameworks by exploring different e-government dimensions in their framework designs. This means that no identified study under the research criteria incorporated any IR 4.0 technologies. Studies by Butt et al. (2020) and Majid et al. (2022) highlighted that there were notable deficiencies within the existing e-government frameworks that did not encompass IR 4.0 technologies. These deficiencies primarily stem from difficulties integrating organizations, discrepancies between design and reality in developing nations, and hindrances in aligning IT infrastructure. Including IR 4.0 technologies is important to synchronize e-government frameworks and enhance service provision, transparency, and efficiency. A comprehensive approach is required to address these deficiencies, considering technological, organizational, and contextual factors.

E-government frameworks that did not utilize IR 4.0 technologies exhibited several significant shortcomings. These encompassed limited technology integration, skill gaps among human resources, challenges pertaining to interoperability, constraints in infrastructure, and an array of barriers impeding successful implementation (Avianto et al., 2022). To adequately address these gaps, a comprehensive approach that considers technological, organizational, and contextual factors is imperative, leveraging advanced technologies, enhancing digital literacy, the digital divide, and ensuring seamless, secure interoperability. Only by doing so the full potential of e-government services can be realized.

3.2.4. E-government Frameworks Leveraging IR 4.0 Technologies

The fusion of cyber-physical systems, artificial intelligence, machine learning, big data analytics, IoT, blockchain, cloud computing, robotics, and automation characterizes IR 4.0 technologies. The concept of digital transformation holds enormous potential for improving e-government services. By integrating these technologies, governments can elevate efficiency, transparency, and service delivery, ultimately enhancing the lives of citizens (Mukherjee, 2022).

This subsection is the main focus of our review as it identifies the existing e-government frameworks that leverage IR 4.0 technologies for transformation and improved public service delivery. The summary of these frameworks is presented in Table 6.

Table 6: Summary of existing e-government frameworks leveraging IR 4.0 technologies

S/N	Framework/ Model/Theory	Main Components	Strengths	Weaknesses	Identified Gaps
1.	A framework for automating e-government services with artificial intelligence (Al-Mushayt, 2019)	1. Management of e-government information resources 2. Deep learning models 3. Smart platform	The framework leverages AI to enhance e-government services.	The framework is limited to the Saudi context.	The framework centers on AI technologies like deep learning, machine learning, and NLP but overlooks other IR 4.0 technologies and security/privacy concerns.
2.	Big data-driven e-government framework in Nigeria (Ogbudju et al., 2019)	1. Centralized data entry point for governance 2. Data harvesting system 3. Sentiment analysis 4. Seamless integration and collaboration of government operations 5. Open data policy application 6. Evidence-based decision making	A comprehensive framework for data-driven governance, enhancing decision-making and transparency.	The framework's reliance on data availability and quality may limit its effectiveness in practice. It is developed for the Nigerian context which might limit its generalizability.	The framework lacks empirical validation, security and privacy considerations, and comprehensive IR 4.0 technology integration.
3.	Big data analytics framework for digital government, Bangladesh (Thamjaroenporn and Achalakul, 2020)	1. Infrastructure 2. HR development 3. Data governance 4. Data catalog 5. Data exchange 6. Laws and regulations 7. Smart and open government	The framework harnesses big data for policymaking and innovations.	Insufficient evaluation and validation processes.	The framework emphasizes the importance of big data for policymaking but lacks integration of other IR 4.0 technologies and overlooks security/privacy risks.
4.	Hybrid e-government framework, Morocco (Oumkaltoum et al., 2021)	1. Data warehousing 2. Multi-agent system 3. ETL processes 4. Materialized views 5. Business intelligence approach	Integrates multiple technologies for data interoperability.	Complexity of the framework; lack of detailed integration with existing systems.	The framework does not discuss IR 4.0 technologies' impact on security and privacy.
5.	E-government data sharing framework based on big data technology, China (Qin et al., 2021)	1. Virtualized database 2. Data service management 3. Multi-node access control technology model based on temporal role-based	The framework focuses on security and efficiency in data exchange.	Research lacks performance assessment of the practical applications of the framework.	The framework emphasizes data exchange efficiency but lacks an in-depth discussion of specific big data technologies and overlooks

S/N	Framework/ Model/Theory	Main Components	Strengths	Weaknesses	Identified Gaps
		access control (T-RBAC) 4. Metadata clustering model 5. Administrative service metadata model			security/privacy implications.
6.	Automatic e-governing system using ML & AI (Prasad and Reddemma, 2022)	1. Government collective office network 2. Big data services center 3. Social public & research 4. Intelligent archives	The framework employs ML and AI technologies to automate e-government services.	Insufficient evaluation and empirical validation processes.	The study applies AI and ML to e-government in Arabic countries but does not consider broader challenges, ethics, and security/privacy concerns.
7.	A secure and privacy-preserving e-government framework using blockchain and artificial immunity (Elisa et al., 2023)	1. Blockchain 2. Artificial immunity system 3. Encryption and validation mechanisms 4. Off-chain storage (sideDB) 5. Smart contracts 6. User authentication and authorization 7. Intruder detection system	Enhanced security through blockchain and artificial immunity integration.	Complexity of the framework; resource-intensive technologies may be unaffordable in a developing country context.	Security and privacy concerns are not fully addressed.
8.	A secure platform for digital governance interoperability and data exchange using blockchain and deep learning-based frameworks (Malik et al., 2023)	1. Blockchain leveraging approach 2. Lightweight Feistel structure with optimal operations 3. Deep reinforcement learning model 4. Blockchain-based data collection 5. Secure platform for data exchange	The framework integrates blockchain and DL for secure data governance.	Complexity of the framework; resource-intensive technologies may be unaffordable in a developing country context.	Limited integration of IR 4.0 technologies.
9.	A framework for digital transformation towards smart governance using big data tools in Ceará, Brazil (Sucupira Furtado et al., 2023)	1. Impact evaluation (Cerebrum, Big Data Social) 2. Urban governance (CZRM, chatbot) 3. Local economy (Ceara app) 4. Digital governance (citizen unique ID) 5. Education and communication	Data-driven decision-making; integration of services.	Research is limited to the province of Ceará, Brazil; it may not be generalizable to other contexts.	Limited exploration of the impact of IR 4.0 technologies.

S/N	Framework/ Model/Theory	Main Components	Strengths	Weaknesses	Identified Gaps
		6. Access to the Internet 7. Financing 8. Integration with UN Sustainable Development Goals			
10.	A novel framework for e-government services with artificial intelligence using CNN (Raja et al., 2023)	1. Deep learning model using CNN 2. AI-integrated systems 3. Smart e-government platform (smart GUI citizen's service layer, security layer, functional layer) 4. Service delivery channels 5. Open data and blockchain technology 6. Learning systems integration 7. Modules for specific tasks 8. Continuous improvement and support	Comprehensive deep learning integration using CNN for service improvement.	The framework does not discuss scalability or resource implications.	The framework focuses on integrating only two IR 4.0 technologies, namely blockchain, and CNNs, while the impact of other IR 4.0 technologies is not explored, leaving gaps in addressing the digital divide, privacy concerns, and accessibility issues for citizens.
11.	Blockchain-based governance models in e-government, India (Mustafa et al., 2024)	1. Legal compliance 2. Data governance ethics 3. Technical efficiency 4. Security and privacy 5. Data minimization 6. Right to erasure 7. Consent management 8. Data access and control	The models assess legal, technical, ethical, and security dimensions using blockchain.	Limited applicability as research was conducted in the specific Indian context.	Research focuses mainly on the blockchain and lacks broader IR 4.0 technology integration.
12.	A framework for blockchain-based transformation projects (Wamba et al., 2024)	Blockchain	The framework can potentially enhance public services, boost administrative efficiency, and reduce corruption through blockchain.	The framework may face challenges in implementation due to varying blockchain adoption and resource requirements.	The framework lacks empirical evidence across diverse government contexts and does not address scalability challenges.

Table 6 presents an overview of 12 e-government frameworks, illustrating diverse approaches to digital governance across various contexts. These frameworks incorporate technologies such as

artificial intelligence, big data, blockchain, etc., each enhancing efficiency, transparency, and citizen participation. Common challenges include complexity, limited scalability, and a narrow focus on specific technologies. One notable observation is the underrepresentation of the integration of comprehensive IR 4.0 technologies. This analysis underscores the need for further research to develop more integrated, scalable, and adaptable e-government solutions, contributing to the evolving discourse in public administration technology.

3.3 Ethical Issues in E-Government Related to the Use of IR 4.0 Technologies

Integrating IR 4.0 technologies into e-government transformational initiatives presents significant opportunities for enhancing public services. Nevertheless, it also gives rise to various ethical concerns that require attention to ensure responsible and equitable use of these technologies.

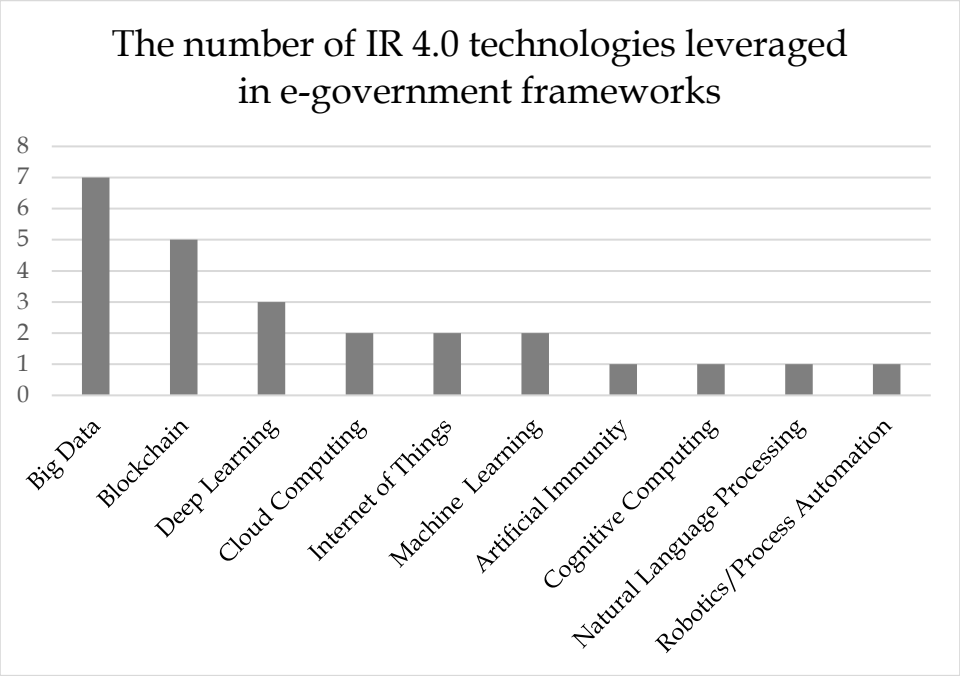
Al-Besher and Kumar (2022) and Pakhnenko and Kuan (2023) highlighted the ethical implications of the utilization of IR 4.0 technologies, which encompass a wide range of concerns such as privacy, security, data protection, transparency, accountability, inclusion, accessibility, and non-discrimination The swift integration of IR 4.0 technologies, particularly artificial intelligence, brings dilemmas that impact moral agency, human relationships, cognitive abilities, freedom, privacy, and the dignity of work (Peckham, 2021).

Addressing these ethical challenges necessitates formulating and designing comprehensive ethical frameworks and policies to steer the conscientious utilization of digital technologies in public administration for efficient service delivery. Ensuring the ethical deployment of these technologies in e-government will enforce trust and social justice and guarantee equitable access to the advantages of digital transformation for all. Ethical privacy frameworks are needed to restore the trust and confidence of citizen users of government websites, addressing concerns related to privacy and security (Manoharan & Carrizales, 2021).

3.4 The Role of IR 4.0 Technologies in E-Government Frameworks

Studies reviewed in Subsection 3.2.4 have integrated IR 4.0 technologies into e-government frameworks, as illustrated in Figure 2. Specifically, seven studies have utilized big data to improve various e-government aspects. Five studies have incorporated blockchain to enhance e-government transformation, while deep learning has been employed in three studies. Cloud computing, the Internet of Things, and machine learning were integrated into two frameworks. Artificial immunity, cognitive computing, natural language processing, and robotics/process automation have been implemented in one study each.

Figure 2: Integration of IR 4.0 technologies in e-government frameworks



The reviewed publications highlighted the potential of IR 4.0 technologies to transform and improve government services, operations, decision-making, and citizen engagement. However, the proposed frameworks often failed to fully integrate these emerging technologies into a comprehensive e-government transformation strategy. The analysis revealed that even if a framework incorporated one or two IR 4.0 technologies, it lacked the main point of utilizing comprehensively the IR 4.0 technologies in improving the entire e-government services to increase democracy, encouraging citizens' participation in decision-making processes, eliminating the digital divide, providing equal prospects for engagement and participation (Mustafa et al., 2024). The analysis revealed that big data analytics and blockchain were the most incorporated IR 4.0 technologies in the reviewed studies.

Table 7 compares 11 e-government frameworks and their adoption of IR 4.0 technologies, including big data analytics, blockchain, cloud computing, cognitive computing, deep learning, Internet of Things, machine learning, natural language processing, and robotics/ process automation. Each framework was associated with specific technologies leveraged to enhance e-government services and processes.

Table 7: IR 4.0 technologies leveraged per e-government frameworks

Frameworks	Emerging IR 4.0 Technologies Leveraged Per Framework									
	Artificial Immunity	Big Data	Blockchain	Cloud Computing	Cognitive Computing	Deep Learning	Internet of Things	Machine Learning	Natural Language Processing	Robotics/ Process Automation
A framework for automating e-government services with artificial intelligence (Al-Mushayt, 2019)		✓		✓		✓	✓			
Big data-driven e-government framework (Ogbudju et al., 2019)		✓								
Big data analytics framework for digital government, Bangladesh (Thamjaroenporn and Achalakul, 2020)		✓								
Hybrid e-government framework, Morocco (Oumkaltoum et al., 2021)		✓								
E-government data sharing framework based on big data technology (Qin et al., 2021)		✓								
Automatic e-governing system using ML & AI (Prasad & Reddemma, 2022)		✓	✓	✓		✓	✓	✓		
A secure and privacy-preserving e-government framework using blockchain and artificial immunity (Elisa et al., 2023)	✓		✓							
A secure platform for digital governance interoperability and data exchange using blockchain and deep learning-based frameworks (Malik et al., 2023)			✓			✓				
A framework for digital transformation towards smart governance using big data tools, Ceará, Brazil (Sucupira Furtado et al., 2023)		✓								
A novel framework for e-government services with artificial intelligence using CNN (Raja et al., 2023)					✓			✓	✓	✓

Frameworks	Emerging IR 4.0 Technologies Leveraged Per Framework									
	Artificial Immunity	Big Data	Blockchain	Cloud Computing	Cognitive Computing	Deep Learning	Internet of Things	Machine Learning	Natural Language Processing	Robotics/ Process Automation
Blockchain-based governance models in e-government (Mustafa et al., 2024)			✓							
A framework for blockchain-based transformation projects (Wamba et al., 2024)			✓							

As demonstrated in Table 7, a framework designed by Prasad and Reddemma (2022) incorporated six IR 4.0 technologies to improve e-government services to enhance democracy in the context of Arabic countries. The studies by Al-Mushayt (2019) and Raja et al. (2023) integrated four IR 4.0 technologies. Elisa et al. (2023) and Malik et al. (2023) utilized two IR 4.0 technologies. All other reviewed e-government frameworks incorporated only one IR 4.0 technology (Ogbudju et al., 2019; Thamjaroenporn and Achalakul, 2020; Oumkaltoum et al., 2021; Qin et al., 2021; Sucupira Furtado et al., 2023; Mustafa et al., 2024; Wamba et al., 2024).

4. Discussion of Research Findings

4.1. Overview of Existing Frameworks

The systematic review identified a range of e-government frameworks leveraging various IR 4.0 technologies across different countries and contexts as a main focus. The review also reviewed a range of frameworks that did not explore the use of IR 4.0 in e-government but where these technologies can be potentially integrated, where they only focused on different e-government dimensions guides in their framework designs. Most studies concentrated on emerging economies, with significant contributions from China, India, and South Africa. The predominance of qualitative research methods (fourteen out of thirty-six studies) indicates a strong focus on understanding contextual and theoretical foundations. Quantitative and mixed methods were also employed, highlighting the diverse approaches to studying e-government transformations.

4.2. Integration of IR 4.0 Technologies

The review revealed that while there is significant interest in integrating IR 4.0 technologies into e-government frameworks, the extent and comprehensiveness of this integration vary. Big data and blockchain were the most commonly leveraged technologies, featured in seven and five frameworks, respectively. Specifically, blockchain technology demonstrated its potential to enhance security and

transparency in e-government processes. Deep learning, although promising, was only utilized in three studies, suggesting a need for further exploration of its applications in this domain.

Cloud computing, the Internet of Things, and machine learning were each utilized in two studies. Artificial immunity (a subfield of artificial intelligence), cognitive computing, natural language processing, and robotics/process automation were each implemented in one study. This limited incorporation of diverse IR 4.0 technologies underscored a significant gap in the current frameworks.

The study also explored studies that looked at the use of IR 4.0 in e-government but did not propose any frameworks or models. Each study typically focused on one IR 4.0 technology. These studies considered artificial intelligence, blockchain, the Internet of Things, and robotics/process automation. The inclusion of IR 4.0 technologies in e-government without a guiding framework poses several risks and disadvantages like lack of standardization, privacy violations, security violations, increased digital divide, ethical concerns, accountability and transparency, public trust and acceptability, compliance and regulatory issues, and many other issues that can potentially hinder the full benefit of the advanced technologies in e-government implementation.

Conclusively, this means that many studies did not address the potential of a comprehensive IR 4.0 integration due to their lack of incorporating comprehensively, the IR 4.0 technology to cover all the e-government transformation aspects.

4.3. Strengths and Weaknesses of Reviewed Frameworks

The reviewed frameworks exhibit several strengths, such as enhanced security, improved service delivery, and increased citizen engagement. For instance, the AI framework for automating e-government services in Saudi Arabia (Al-Mushayt, 2019) and the blockchain-based governance models in India (Mustafa et al., 2024) demonstrate how specific IR 4.0 technologies can drive significant improvements in e-government.

However, these frameworks also have notable weaknesses. Many are context-specific, limiting their generalizability to other regions or countries. Additionally, the complexity of some frameworks, such as the cognitive analytics management framework in Turkey (Osman et al., 2019), poses challenges for practical implementation. The lack of comprehensive IR 4.0 integration in most frameworks points to an underutilization of the full potential of these technologies.

4.4. Identified Gaps and Recommendations for Future Framework Development

The analysis identified several gaps in the current e-government frameworks. The first identified gap is the limited integration of IR 4.0 technologies, as many frameworks incorporate only one or two IR 4.0 technologies, missing out on the synergistic benefits of a more comprehensive approach. The second gap is the lack of scalability and generalizability, as frameworks are often tailored to specific contexts, limiting their applicability in different settings. The third gap is the lack of comprehensive coverage of security and privacy, for instance, in studies by Al-Mushayt (2019), Ogbudju et al. (2019), Thamjaroenporn and Achalakul (2020), Qin et al. (2021), and Prasad and

Reddemma, (2022). While some frameworks integrate security and privacy concerns, these aspects are not holistically addressed, especially in frameworks not leveraging blockchain technology. Finally, only a few frameworks address the digital divide, an essential consideration for ensuring inclusive and democratic e-government services.

To address these gaps, future e-government frameworks should, first, comprehensively leverage the full spectrum of IR 4.0 technologies, including AI, machine learning, big data analytics, blockchain, IoT, cloud computing, cognitive computing, and autonomous robots, to enhance service delivery and citizen engagement comprehensively. Further research should focus on developing and testing comprehensive e-government frameworks integrating multiple IR 4.0 technologies. Second, future e-government frameworks should be scalable, flexible, and adaptable to different contexts and regions, ensuring broader applicability and impact. Empirical studies evaluating the effectiveness of these frameworks in diverse contexts will be crucial for refining and validating their design and implementation. Third, future e-government frameworks must incorporate robust security and privacy measures, particularly leveraging blockchain technology, to protect sensitive government data and citizen information. Lastly, e-government frameworks must include strategies to bridge the digital divide, ensuring all citizens have equal access to e-government services and fostering greater inclusivity and democratic participation.

4.5. Study Contribution and Implications

This paper contributes to the development and implementation of e-government frameworks by highlighting the transformative potential of IR 4.0 technologies, such as AI, big data, and blockchain. Policymakers and government agencies can leverage these insights to formulate policies that prioritize the integration of these technologies to enhance public service delivery, increase transparency, and foster citizen engagement. The practical implications of this study extend to the design of more comprehensive and secure e-government systems that address key concerns, including data security, privacy, and the digital divide. By identifying gaps in current frameworks, this paper provides a roadmap for developing more robust, scalable, and adaptable e-government solutions that can be effectively implemented across diverse geopolitical contexts. Ultimately, this research supports the creation of e-government systems that are not only technologically advanced but also inclusive, secure, and aligned with democratic values.

5. Conclusion, Limitations, and Future Work

5.1. Conclusion

This systematic review highlights the transformative potential of IR 4.0 technologies in enhancing e-government services, focusing on democratizing public administration through improved transparency, citizen engagement, and service delivery. The study examined a range of existing frameworks, identifying significant gaps in the comprehensive integration of IR 4.0 technologies. While many frameworks demonstrated advancements in specific areas, such as security through blockchain and efficiency through artificial intelligence, the lack of holistic integration across diverse

technologies such as big data, IoT, machine learning, and cognitive computing was evident. This gap underscores the necessity for developing more robust, scalable, and adaptable frameworks that fully leverage the capabilities of IR 4.0 technologies to achieve inclusive and democratic e-government systems.

5.2. Limitations

Despite its comprehensive approach, this study has several limitations. First, the review was restricted to literature published between 2019 and 2024, potentially overlooking earlier works that might provide foundational insights into e-government frameworks. Additionally, the study focused exclusively on English-language publications, which may have excluded significant research published in other languages, particularly in non-English-speaking regions where e-government initiatives are also advancing. Furthermore, the review primarily emphasized the theoretical and conceptual aspects of e-government frameworks, potentially underrepresenting practical, real-world implementations that could offer valuable insights into the challenges and successes of integrating IR 4.0 technologies.

5.3. Future Work

Future research should aim to address these limitations by expanding the review to include literature from a broader time frame and incorporating multilingual sources. There is also a need for empirical studies that assess the practical application of IR 4.0 technologies in e-government, particularly in diverse geopolitical contexts. Such studies should explore the scalability and adaptability of existing frameworks, ensuring they can be applied effectively across different regions and administrative structures. Additionally, future frameworks should prioritize the ethical considerations of integrating advanced technologies addressing issues such as data privacy, security, and the digital divide. This will ensure that the benefits of IR 4.0 technologies in e-government are realized equitably, fostering greater inclusivity and trust in public administration systems.

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