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Review

Modelling Factors Influencing IoT Adoption: With a Focus on Agricultural Logistics Operations

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Abstract: Purpose- In recent years, there has been a notable surge in the utilization of emerging technologies, notably the Internet of Things (IoT), within the realm of business operations. However, empirical evidence has underscored a disconcerting trend whereby a substantial majority, surpassing 70%, of IoT adoption initiatives falter when confronted with the rigors of real-world implementation. Given the profound implications of IoT in augmenting product quality, this study endeavors to scrutinize the extant body of knowledge concerning IoT integration within the domain of agricultural logistics operations. Furthermore, it aims to discern the pivotal determinants that exert influence over the successful assimilation of IoT within business operations, with particular emphasis on logistics. **Design/Methodology/Approach**- The research utilizes a thorough systematic review methodology coupled with a meta-synthesis approach. In order to identify and clarify the key factors that influence IoT implementation in logistics operations, the study is grounded in the Resource-Based View theory. It employs rigorous grounded theory coding procedures, supported by the analytical capabilities of MAXQDA software. **Findings**- The culmination of the meta-synthesis endeavor culminates in the conceptual representation of IoT adoption within the agricultural logistics domain. This representation is underpinned by the identification of three overarching macro categories/constructs, namely: (1) IoT Technology Adoption, encompassing facets such as IoT implementation requisites, ancillary technologies essential for IoT integration, impediments encountered in IoT implementation, and the multifaceted factors that influence IoT adoption; (2) IoT-Driven Logistics Management, encompassing IoT-based warehousing practices, governance-related considerations, and the environmental parameters entailed in IoT-enabled logistics; and (3) the Prospective Gains Encompassing IoT Deployment, incorporating the financial, economic, operational, and sociocultural ramifications ensuing from IoT integration. The findings underscore the imperative of comprehensively addressing these factors for the successful assimilation of IoT within agricultural logistics processes. **Originality**- The originality of this research study lies in its pioneering effort to proffer a conceptual framework that furnishes a comprehensive panorama of the determinants that underpin IoT adoption, thereby ensuring its efficacious implementation within the ambit of agricultural logistics operations. **Practical Implications**- The developed framework, by bestowing upon stakeholders an incisive comprehension of the multifaceted factors that steer IoT adoption, holds the potential to streamline the IoT integration process. Moreover, it affords an avenue for harnessing the full spectrum of IoT-derived benefits within the intricate milieu of agricultural logistics operations.

Keywords: agricultural logistics operations; IoT; systematic literature review; meta-synthesis method

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1. Introduction

In recent years, there has been a growing emphasis on the effective management of agricultural logistics operations and the enhancement of agricultural product quality [1]. Numerous agricultural organizations have embarked on the adoption of innovative operational strategies and digital solutions, such as the Internet of Things (IoT) [2–4], to augment their logistics and supply chain functions [5].

Within the realm of logistics operations, IoT plays a pivotal role in quantifying the safety and quality aspects of food products by providing transparency into their growth, handling, storage, and transportation across the entire supply chain [6]. Consequently, IoT is anticipated to exert a substantial influence on the enhancement of agricultural logistics management through the facilitation of digitalization and integration within the supply chain [7].

This integration of supply chains can pave the way for the establishment of interconnected, transparent, and responsive supply networks [8–10]. Enhanced inter-organizational collaboration within food and agricultural supply chains can effectively address critical challenges, including traceability and perishability, resulting in noteworthy improvements in product quality and a subsequent reduction in waste within logistics operations [3,11–15].

Gap in Knowledge

IoT technology has a substantial impact on agricultural logistics operations [16,17]. It enables real-time monitoring and traceability of products, improving inventory management through sensor-based tracking [18]. By collecting and analyzing data, it optimizes transportation routes, thereby enhancing the efficiency of logistics operations. Additionally, IoT facilitates predictive maintenance of vehicles and equipment, reducing downtime and boosting productivity [16,17]. This technology enhances supply chain visibility and risk management, offering insights into the entire supply chain process [18]. Furthermore, IoT ensures the quality and compliance of agricultural products, which is crucial for maintaining product integrity and regulatory standards [16,17]. These developments are critical for enhancing the efficiency, reliability, and sustainability of agricultural logistics, ultimately benefiting both producers and consumers [16,17]. Table 1 provides a summary of studies investigating impact of IoT in agricultural operations.

Despite the significant potential of IoT adoption in improving the performance of logistics operations, it is noteworthy that a substantial 75% of IoT adoption projects encounter failure when implemented in real-world scenarios. This pervasive issue hampers progress in the deployment of IoT solutions. A primary factor contributing to this failure is the absence of comprehensive planning and effective implementation strategies, coupled with a limited comprehension of the factors that shape IoT adoption [19].

Prior research has primarily delved into the impact of IoT within the distribution phase of agricultural supply chains (e.g., [20–22]) or has provided frameworks to enhance inventory transparency [23]. Some studies have centered on IoT's influence on risk management and information flow management within agricultural operations [24–26]. Similarly, Alifah [27] endeavored to establish a three-layer architecture for IoT implementation within the logistics process of the rice supply chain in Indonesia. Certain researchers have also examined the role of IoT enablers in agricultural operations [28]. Other studies concerning IoT implementation have concentrated on analyzing the challenges and barriers to adoption (e.g., Refs. [28–30]) or have endeavored to formulate business models for IoT adoption and applications [31,32].

However, to the best of our knowledge, existing research lacks a comprehensive approach to IoT adoption in agricultural logistics operations and a systematic categorization of the factors influencing IoT adoption. Furthermore, most studies concerning IoT implementation in agricultural operations predominantly center on the delivery and production processes [33], with limited attention afforded to logistics operations. Similarly, it is argued that scant research has been conducted on establishing secure agricultural logistics operations through IoT [6].

To bridge the theoretical gaps highlighted above, this study employs the Resource-Based View (RBV) theory and a meta-synthesis approach. The goal is to take a comprehensive view, identifying the multifaceted factors that influence the adoption of Internet of Things (IoT) technology in agricultural logistics operations. Furthermore, this research endeavor aims to construct a conceptual model through the meta-synthesis method, delving into the intricate interconnections among these influential factors. The following research questions guide our investigation:

(1) What is the current state of knowledge about IoT adoption in agricultural operations and its potential impact on the logistics process?

(2) What are the key factors affecting IoT adoption and implementation in business operations such as logistics?

The structure of our paper is thoughtfully designed to provide a coherent and logical flow of information. We commenced the paper with an Introduction and Gap section, which serves as a solid foundation for understanding the context and the research problem. Following this introduction, we dedicated Section 2 to offering a concise background on agricultural supply chains, thus ensuring readers have the necessary background to comprehend the study's context. In Section 3, we delved into the intricacies of Internet of Things (IoT) to equip our audience with a clear understanding of the technology's relevance to the agricultural supply chain. Moving on to Section 4, we presented an in-depth exploration of the current state of knowledge concerning IoT adoption and implementation. This well-structured progression ensures that readers are gradually led into the heart of the study's core issues. Subsequently, we discussed our methodology, highlighting the theoretical underpinning, quality control measures, and data analysis techniques employed, all of which are essential components of rigorous research. To culminate our study, we provided the findings derived from our research, which ultimately led to the development of the final framework. This carefully planned paper structure optimizes the reader's understanding of the research process, from background knowledge to empirical findings, thus facilitating a comprehensive exploration of the subject matter.

Table 1. IoT benefits in agricultural supply chains.

Authors	Relation to Agricultural Logistics Operations	Hypothetical Results/Findings
Leng et al. [20]	Impact of IoT on distribution in agricultural supply chains	Improved distribution efficiency, reduced spoilage, faster delivery times
Zhang et al. [22]	Impact of IoT on distribution in agricultural supply chains	Increased accuracy in product distribution and minimized losses
Srinivasan et al. [23]	Frameworks for enhancing inventory transparency	Real-time inventory visibility, optimization, and reduced carrying costs
Duan [24]	IoT's influence on risk management and information flow	Improved risk assessment and mitigation, smoother information flow
Mo [25]	IoT's influence on risk management and information flow	Enhanced risk management and information sharing in agricultural operations
Yan et al. [26]	IoT's influence on risk management and information flow	Improved risk mitigation and efficient information exchange
Alifah et al. [27]	Three-layer architecture for IoT in rice supply chain	Enhanced efficiency and traceability in the rice supply chain
Yadav, Luthra, & Garg [28]	Role of IoT enablers in agricultural operations	Successful integration of IoT technologies into agricultural logistics

Table 1. *Cont.*

Authors	Relation to Agricultural Logistics Operations	Hypothetical Results/Findings
Aamer, Al-Awlaqi, Affia, Arumsari, & Mandahawi [29])	Analysis of challenges and barriers to IoT adoption	Identification of common obstacles in IoT implementation
Lin, Lee, & Lin [30]	Analysis of challenges and barriers to IoT adoption	Identification of challenges faced during IoT implementation
Mattos and Novais Filho [31]	Formulation of business models for IoT adoption	Proposed business models for IoT implementation in agriculture
Del Sarto et al. [32]	Formulation of business models for IoT adoption	Economic feasibility and potential returns on investment in IoT adoption

2. Agricultural Supply Chain and Logistics Background

Agricultural supply chain management has long been acknowledged as an exceptionally challenging and pivotal domain of management. Its intricacies are chiefly underscored by factors such as food quality, safety assurance, and weather-related variables, setting it apart from other logistical operations [2,15,34–36]. The task of upholding quality standards within food supply chains is compounded by the dual concerns of ensuring food safety [37] and grappling with machinery breakdowns [38].

Agricultural supply chains are further distinguished by characteristics such as perishability, limited shelf life, fluctuations in quality and quantity, and specialized transportation requisites (2). Moreover, the inherent contamination risks associated with production processes present formidable challenges in the management of agricultural logistics operations while striving to sustain quality benchmarks. Substandard and defective products, coupled with inferior quality, lead to the generation of substantial waste volumes [39,40]. The substantial magnitude of waste generated by agricultural products constitutes a pressing predicament within agricultural supply chains.

Waste concerns can also arise from inadequate monitoring and supervision throughout the supply chain's product movement and storage processes. For instance, research by the American Natural Resources Defense Council has revealed that as much as 40% of food is lost from the farm to the consumer's table in the United States [41]. Consequently, the effective management of agricultural products assumes a paramount role within the realm of agricultural logistics operations [35].

Table 2 summarizes various studies and their key issues/findings related to agricultural supply chains, including some recent research.

Table 2. Key studies around agricultural supply chains.

Author (Year)	Study/Paper Title	Key Issues/Findings
Smith [42]	Challenges in Agricultural Supply Chains	Lack of transparency in supply chain operations, inefficient transportation and distribution, quality control issues leading to product losses.
Brown [43]	Sustainability in Agricultural Supply Chains	Environmental concerns (e.g., pesticide use), social issues (e.g., labor conditions), the need for sustainable sourcing and practices.

Table 2. *Cont.*

Author (Year)	Study/Paper Title	Key Issues/Findings
Johnson [44]	Resilience of Agricultural Supply Chains	Vulnerability to extreme weather events, dependence on a limited number of suppliers, lack of contingency plans for disruptions.
Gupta [45]	Technological Innovations in Agricultural Supply Chains	Potential benefits of IoT and blockchain technology, data-driven supply chain optimization, improved traceability and food safety.

3. Internet of Things

Consumer demands for increased quality and safety in agricultural products have surged, underscoring the growing significance of product tracking and logistics monitoring within the food supply chain. Within the context of Industry 4.0, the Internet of Things (IoT) emerges as a highly promising paradigm for bolstering product quality and safety [46]. IoT achieves this by enabling a heightened level of oversight and control over logistical operations [47–51], thereby fostering improvements in supply chain sustainability [47,52,53].

Furthermore, IoT contributes to intelligent logistics management and efficient product tracking by facilitating automated decision-making with minimal human intervention. This is achieved through the integration and empowerment of communication technologies, such as Radio-Frequency Identification (RFID), wireless sensor networks, Machine-to-Machine (M2M) systems, mobile software, and others, which enable real-time product monitoring and tracking across the entire supply chain [50,54,55]. Consequently, IoT is poised to revolutionize agricultural logistics operations by enhancing visibility and facilitating access to up-to-the-minute information [12,15,37,53,56].

The Internet of Things (IoT) has had a profound impact on agricultural supply chains, revolutionizing the way farms and agribusinesses operate. IoT devices, such as sensors, have been instrumental in providing real-time data on various aspects of agriculture, from soil conditions to crop health [42]. These sensors transmit data to central systems, allowing farmers to make data-driven decisions. For example, IoT-enabled soil moisture sensors can provide accurate information on soil conditions [43]. This data empowers farmers to optimize irrigation, conserve water resources, and enhance crop yields. Moreover, IoT technology has transformed the monitoring of livestock, allowing farmers to track the health and location of individual animals, leading to improved animal welfare and disease prevention [44]. In the supply chain, IoT-enabled tracking and tracing mechanisms provide valuable insights into the movement of agricultural products, ensuring freshness and reducing food waste. In essence, IoT technology is a game-changer for the agricultural industry, enhancing efficiency, sustainability, and transparency throughout the supply chain [45].

4. Current State of Knowledge on IoT Adoption and Implementation

The application of Internet of Things (IoT) technology holds the promise of a revolutionary impact on the agricultural industry. This potential transformation encompasses multifaceted improvements in supply chain efficiency, productivity enhancement, and heightened levels of product safety and quality [57–59]. Several in-depth investigations have explored the ramifications of IoT adoption within agricultural logistics operations. For instance, Li et al. [60] concentrated their efforts on IoT technology's application in cold chain monitoring during the transportation of perishable produce. Their findings substantiated that IoT-based cold chain monitoring contributes significantly to supply chain and logistics optimization by mitigating spoilage, reducing waste, enhancing food safety, and fostering transparency within the supply chain.

Similarly, Miah et al. [61] scrutinized the deployment of IoT-enabled precision agriculture for sustainable food production. Their research highlighted the capacity of IoT technology to elevate crop yields, diminish water and fertilizer consumption, and elevate the overall operational efficiency in agriculture. However, they also underscored the necessity of addressing pertinent challenges related to data management, connectivity, and security within the IoT-enabled precision agriculture framework. Miao et al. [62] provided a comprehensive overview of IoT applications in agriculture, notably showcasing smart farming systems that harness IoT technology for real-time monitoring and optimization of crop growth, soil moisture levels, and temperature. This holistic analysis emphasized the potential advantages associated with IoT-driven smart farming, such as increased crop yields, reduced water utilization, and heightened operational efficiency.

Furthermore, Islam et al. [63] delved into the utilization of IoT technology for traceability within the food supply chain. Their research illuminated that IoT-enabled traceability can be instrumental in elevating food safety standards, augmenting operational transparency, and bolstering consumer trust. Nevertheless, their study also underscored the imperative need for standardized regulations to ensure the reliability and interoperability of IoT-enabled traceability systems.

In light of these empirical investigations, it becomes evident that IoT-based applications, encompassing smart farming systems, cold chain monitoring, precision agriculture, and traceability systems, possess the potential to confer substantial benefits upon the agricultural industry. Furthermore, numerous studies have examined diverse facets of IoT adoption and implementation, encapsulating IoT applications and operational paradigms.

For instance, Ref. [26] focused on fundamental elements of agricultural logistics operations and formulated an IoT-based agricultural model predicated upon three strata of this technology. This model segmented the entire agricultural supply chain into discrete phases, encompassing production, processing, distribution, retail, and ultimate consumption. Within this framework, real-time monitoring of seed growth conditions via temperature and humidity sensors featured prominently in the production phase. In processing operations, manufacturers affixed RFID tags to processed products for seamless information retrieval. Distribution processes were underpinned by GPS-equipped vehicles to ensure product safety. Concurrently, consumers could access real-time product information in the retail phase through product packaging barcodes. The network layer facilitated information processing, transmission, and dissemination through the internet, encompassing data pertaining to product origin, growing conditions, market pricing, vehicle tracking, and various stakeholders. The implementation layer empowered suppliers to tailor agricultural products to market demand and customer requisites. Moreover, purchasers could adjust production plans based on the evaluation of supplier product quality and prior-year revenues. Regulatory entities could leverage the tracking system to identify and prosecute responsible parties, while consumers could scrutinize agricultural product safety and quality before purchase.

Similarly, [64] highlighted the challenges encountered by agricultural supply chains concerning real-time IoT-derived data. Their innovative model incorporated two-echelon supply hubs within perishable food supply chain operations. This design leveraged geographical proximity to endow upstream and downstream supply centers with the capacity to offer logistics services while responding adeptly to operational contingencies. Factors influencing IoT adoption in logistics and supply chain operations, including suppliers, supply centers, manufacturers, retailers, IoT configuration, and information-sharing platforms, were meticulously considered within this framework.

Furthermore, Lee and Lee [65] undertook a comprehensive investigation into network technology solutions for designing IoT models tailored to agricultural product distribution and information system construction. This model aimed to facilitate real-time processing, information sharing, and comprehensive tracking and monitoring of agricultural product safety across the supply chain. It sought to address quality and safety concerns in agricultural products, spanning the entire production-to-consumption continuum.

Chen [66] introduced an agricultural logistics model grounded in the Internet of Things. He argued that key influencers in IoT implementation within agricultural logistics encompassed participants from both upstream and downstream segments of the supply chain, including core businesses, small and medium-sized support organizations, banks, logistics service providers, technological support entities, and educational institutions. Chen's study advocated government intervention to create a conducive environment for IoT development, thereby addressing key implementation challenges such as network security and standardization of supply chain and logistics information flow and management platform. This intervention, in turn, could pave the way for gradual expansion of pilot implementations throughout the supply network and the establishment of uniform IoT implementation standards.

Moreover, Duan [24] introduced a model elucidating the information flow within an IoT-driven agricultural supply chain. His research underscored the primary objectives of an IoT-based agricultural logistics platform, encompassing the enhancement of data collection speed and accuracy, reliable integrated data transmission, improved central processing capabilities, real-time search capabilities, traceable information provision, and advanced intelligent services. Duan's model advocated the integration of diverse types of information spanning agricultural production, procurement, warehousing, transportation, delivery, and retail, thereby fostering seamless information exchange across different phases of the supply chain.

Finally, the study by Ref. [27] addressed the specific challenges and complexities of the rice supply chain in Indonesia, where ensuring the efficient and timely delivery of rice is of paramount importance. The three-layer architecture proposed in their research aimed to leverage IoT technology to streamline and enhance various aspects of the rice logistics process.

Layer 1: Data Acquisition and Sensing

In the first layer of the architecture, the researchers likely proposed the deployment of IoT sensors and devices for data acquisition. These sensors could be placed at critical points along the rice supply chain, including in the fields, during transportation, and at storage facilities. They would collect data on various parameters such as temperature, humidity, location, and quality of the rice. The results of this layer may have demonstrated how IoT sensors enable real-time data collection, ensuring the quality and condition of rice is maintained throughout its journey in the supply chain.

Layer 2: Data Processing and Communication

The second layer of the architecture would focus on processing and communication. IoT-generated data would be collected, processed, and transmitted to a central system. This layer would include data analytics and communication protocols to facilitate the seamless flow of information. The study's findings may have highlighted how this layer optimizes decision-making by providing real-time insights into the rice supply chain. For instance, it could help in identifying potential delays, quality issues, or bottlenecks in the logistics process.

Layer 3: Decision Support and Action

The third layer of the architecture likely involved decision support and action. The processed data from the second layer would be used to make informed decisions and take necessary actions. For example, if the data indicated that a shipment of rice was exposed to unfavorable environmental conditions during transportation, the system could trigger alerts for corrective actions. The results of this layer may have demonstrated how this architecture contributes to proactive decision-making, reducing losses and enhancing the overall efficiency of the rice supply chain in Indonesia.

In summary, Ref. [27]'s study presented a three-layer architecture for IoT implementation in the rice supply chain. The results of this research could have shown that this architecture significantly improves the quality, efficiency, and traceability of rice logistics operations in Indonesia by leveraging IoT technology. It enables real-time data monitoring, informed decision-making, and proactive responses to issues, ultimately benefiting both producers and consumers in the rice supply chain.

Other than the studies discussed above, systematic review methodologies have been employed to examine IoT's role within agricultural logistics operations. For instance, Kodan et al. [67] offered a comprehensive discussion of current and future developments in IoT within the food and agriculture supply chain. They noted the food industry's resilience in adapting to IoT-induced changes while highlighting challenges pertaining to terminology standardization and the analysis of large datasets for traceability purposes. Similarly, Ben-Daya [33] conducted a review of IoT and food logistics management, revealing a predominant focus on conceptual frameworks and a paucity of analytical models and experimental studies.

In sum, the confluence of empirical research and systematic evaluations underscores the transformative potential of IoT technology in revolutionizing the agricultural industry and its supply chain operations. It also elucidates the multifaceted considerations necessary for successful IoT adoption and implementation within this context. Table 3 provides a summary of proposed models for IoT adoption and implementation in agricultural supply chains.

Table 3. Models for IoT adoption and implementation in agricultural logistics operations.

Author Name & Year.	IoT Adoption Model/Framework	Impact
Miao et al. [62]	IoT-based Smart Agriculture System	Improved efficiency, reduced costs, better decision-making, and increased productivity
Li et al. [60]	Blockchain and IoT-based Traceability Framework	Improved supply chain transparency, reduced food fraud, and enhanced consumer trust
Sharma et al. [34]	IoT-based Smart Agriculture System	Improved crop yield, reduced wastage, and better resource utilization
Gupta et al. [45]	IoT-enabled Supply Chain Management System	Improved transparency, traceability, and quality control in the supply chain
Miah et al. [61]	IoT-based Crop Monitoring and Management System	Improved crop yield, reduced resource consumption, and increased efficiency
Leng et al. [20]	Identification of agricultural products using IoT	Improved traceability and transparency in the supply chain
Alifah et al. [27]	IoT-based logistics architecture	Improved efficiency and effectiveness of logistics processes in the supply chain
Srinivasan et al. [23]	IoT-based transparency framework	Improved inventory management and visibility in the supply chain
Yan et al. [26]	Mathematical model for risk management using IoT	Improved risk management and decision-making in the supply chain
Zhang et al. [22]	IoT-based supply network modelling	Improved understanding and analysis of supply network dynamics

5. Materials and Methods

5.1. Resource Based View Theory

The Resource-Based View (RBV) theory asserts that a firm's competitive advantage primarily hinges on its unique and valuable resources and capabilities. In the realm of technology adoption, RBV theory posits that firms equipped with superior resources and capabilities are better positioned to embrace and effectively implement new technologies [68,69]. A compelling illustration of the applicability of RBV to technology adoption is found in the study conducted by Li and Liang [70]. Their research delved into the role of firm resources and capabilities in the adoption of cloud computing technologies within Chinese Small and Medium Enterprises (SMEs). The study's findings revealed that attributes like firm size, IT expertise, and financial resources exerted a positive influence on the adoption of cloud computing technologies.

Another pertinent study underscoring the relevance of RBV in the context of technology adoption is the work of Li and Wang [71]. By applying RBV theory, they investigated the factors affecting technology adoption in Chinese firms. Their conclusions highlighted that RBV theory offers a valuable framework for comprehending the impact of resource-based and institutional factors on technology adoption.

In a similar vein, Chen and Chen [72] engaged in an inquiry into the connection between firm resources and technology adoption through the lens of RBV theory. Their research uncovered a positive association between a firm's resource endowment, including technological capabilities, and its propensity to adopt new technologies. Collectively, these studies affirm that RBV theory provides a valuable framework for understanding the multifaceted factors that influence technology adoption, particularly in industries where technological capabilities play a pivotal role in maintaining a competitive edge.

We have chosen the Resource-Based View (RBV) theory as the framework for modelling the factors influencing Internet of Things (IoT) adoption due to its well-established relevance in the field of technology adoption and its robust explanatory power. RBV theory emphasizes the pivotal role of a firm's internal resources and capabilities in shaping its competitive advantage, making it particularly apt for examining the intricate landscape of IoT adoption. IoT technologies are transformative and require firms to leverage their unique assets, both tangible and intangible, to successfully integrate and harness these innovations. RBV's focus on how a firm's resource endowment, including technological capabilities, influences its propensity to adopt new technologies aligns perfectly with the complexities of IoT adoption. This choice of RBV theory as the foundation for our model provides a coherent and holistic framework for understanding the intricate interplay of factors that drive IoT adoption, ultimately contributing to a more nuanced and comprehensive analysis of this critical phenomenon.

Based on our initial scoping study and using RBV as a theoretical platform we propose the following framework which will be used as a basis for our meta study. Figure 1 provides the preliminary conceptual framework.

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5.2. Research Methodology

This research is based on a qualitative meta-study. In recent years, meta-study has been introduced to examine, combine, and identify weaknesses in previous research studies [73]. This approach includes four methods: meta-analysis, meta-synthesis, meta-theory, and meta-method [74]. In this paper, the meta-synthesis has been used, in which new fundamental topics and metaphors are explored through a combination of different qualitative research methods. This method allows for the creation and expansion of knowledge by enabling a comprehensive analysis of the topic [75]. Sandelowski and Barroso [76] introduced seven steps for the meta-synthesis method that have been used in this study (Figure 2).

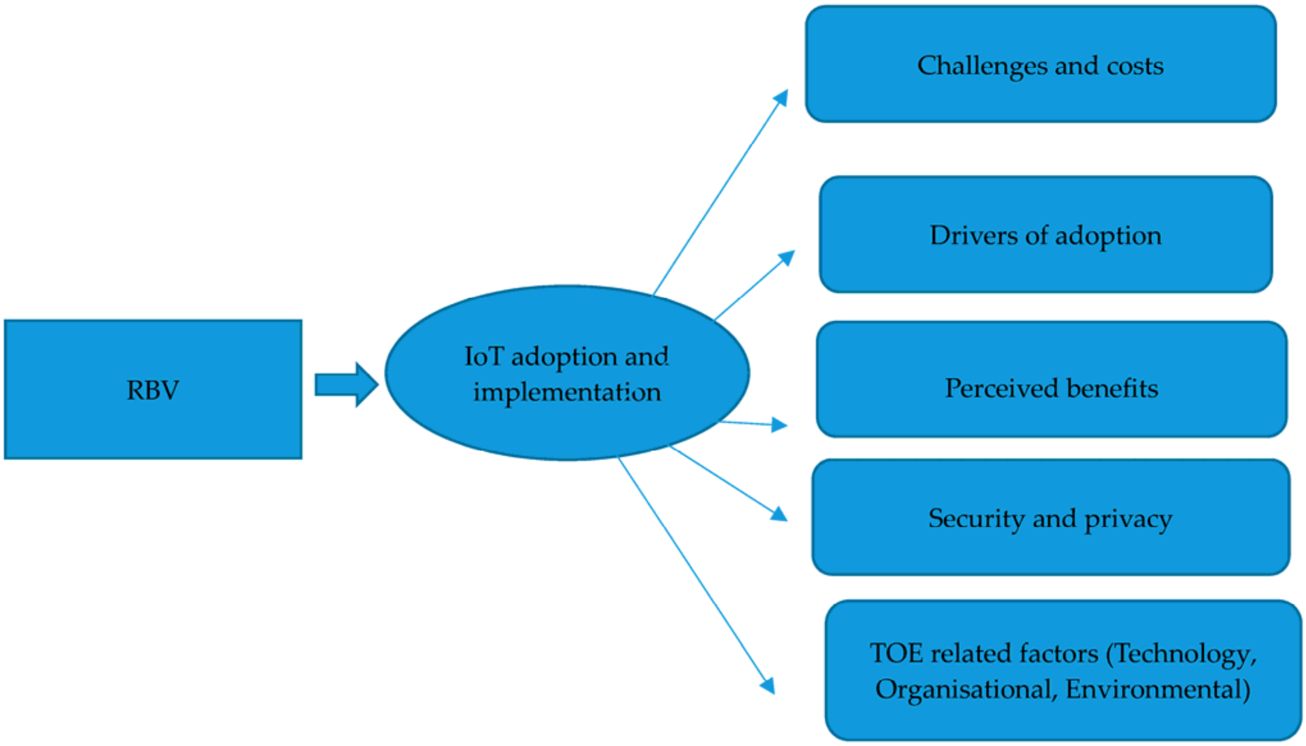

Figure 1. Proposed conceptual framework.

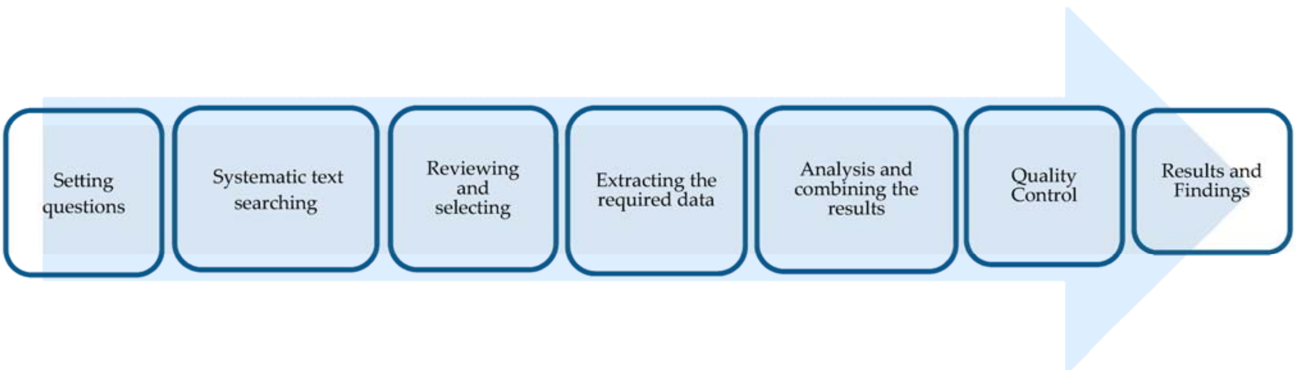

Figure 2. Steps of implementing the meta-combination method.

5.2.1. Setting Questions

In the meta-synthesis method, the first step is to develop the research question, which, in this study, is concerned with investigating the factors influencing IoT adoption and implementation in agricultural logistics operations. Following this, research keywords were developed based on the main question.

5.2.2. Systematic Text Searching

The process of systematic text searching begins with searching databases. In the first step, the Web of Science and Scopus databases were searched using advanced search techniques in the title, abstract, and keyword sections to identify related articles.

5.2.3. Reviewing and Selecting the Appropriate Texts

In this step, the articles that met the inclusion criteria were selected. In the search phase, 163 related articles were identified, of which a total of 68 articles were omitted due to irrelevance or duplication. By reviewing the references of related articles, 11 articles were added to the chosen articles using the backward snowball approach. Finally, 106 articles were selected. In the qualitative screening stage, the identified articles were evaluated and screened using the nine quality metrics introduced by Hauge, Ayala, and Conradi [77] (Table 4). These quality metrics include (1) the research method; (2) research question or purpose; (3) the motivation of research questions; (4) limitations or validity of the article; (5) research field; (6) data collection; (7) data analysis; (8) sampling or selecting studies; and (9) data presentation. During this stage, the selected articles were evaluated based on yes/no values. To do so, one author performed the quality assessment by checking each of those 9 criteria in each study and evaluating them using 0 or 1 values. After that, another author verified the results. Then, the two authors examined the results, and any differences were resolved through discussion between the authors. Finally, based on the qualitative evaluation (Table 5), 61 articles were identified as having higher quality and were fully studied and analyzed descriptively and thematically.

Table 4. Quality assessment: distribution of research papers.

Quality Assessment Score	0	1	2	3	4	5	6	7	8	9	Total
Number of Papers	0	0	2	2	5	5	4	6	11	26	61

Table 5. The process and criteria for selecting articles.

Election Criteria	Description	Results
Paper inclusion criteria	Subject: Articles whose main focus was on the IoT and the agricultural and food supply chain Language: Articles written in English Period: Articles published between 1 January 2005 and 10 November 2020 Type of research: Research articles published in high quality and high impact-factor journals Subject Area: Information systems, management, computer science, social sciences, agricultural and food science	
Keywords	Supply Chain or Logistics Management, Internet of Things or IoT, Agriculture and Food	
Search	Online databases were searched with the above keywords.	Clarivate Analytics & Scopus
Identified articles		163 articles
Synthesis	The results of database searches were considered to examine their relevance through title, abstract and keyword analysis.	
	Unsuitable/irrelevant articles were omitted after first evaluation	68 articles
	Duplicate articles indexed in both Scopus citation database and Web of Science database were removed.	27 articles
	Articles omitted due to lack of focus on the Internet of Things.	12 articles
	Articles omitted due to lack of focus on the agri-food supply chain.	29 articles

Table 5. *Cont.*

Election Criteria	Description	Results
Snowball view	Articles added as a result of using the reversed snowball view	25 articles
	Articles that were removed due to non-compliance with the inclusion and exclusion criteria.	14 articles
Selected sample for analysis		70 articles
Content evaluation	Articles that received high quality rating	61 articles
Final sample		61 articles

Table 4 fully describes the process of searching and selecting reviewed articles.

5.2.4. Extracting and Synthesising Data

In this study, we applied the coding model proposed by Nouri and MehrMohammadi [78] for data analysis. They introduced a simple and flexible coding model based on the technique introduced by Strauss and Corbin [79]. Accordingly, we studied all the selected articles and identified and coded the relevant paragraphs. We extracted the relevant codes from the text of the articles using MAXQDA software, which allowed us to identify key themes and concepts and analyse their interlinks by categorizing them [79] (see Table 6).

Table 6. Classification of Codes, Themes and Categories.

Categories	Themes	Codes
Internet of things adoption	Organizational features	Organizational readiness
		Organization size
		Top management support
		Organizational Culture
		Trust
		Skilled human resources availability
	Environmental features	External pressures
		Governmental support
		Uncertainty
		Time-to-market
	Financial factors	Reduced costs
		Value creation
		Implementation cost (reverse effect)
		High energy consumption (reverse effect)
		Technology cost (reverse effect)
		Long term return on investment (reverse effect)
	Technological features	Perceived benefits
		Complexity

Table 6. *Cont.*

Categories	Themes	Codes
		Adaptability
		Technological infrastructure
		Lack of standardization (reverse effect)
		Safety and privacy
Establishment requirements	Technological requirements	IoT components
		IoT architecture
	Implementation requirements	Budget allocation
		Appropriate technical infrastructure
		Stakeholder cooperation
	Security requirements	Confidentiality
		Authentication
		Access control
		Cyber attacks
		Data security
Challenges of IoT implementation	Economic and social	Long term return on investment
		Cost of implementation
		Environmental changes
		Business model
		Energy efficiency
		Legislation
		Staff training
	Technological	Integration with existing ICT technology
		Non-functional data
		High number of required sensors
		Data reliability
		Standardization
	Security and privacy	Scalability of data
		Networking
		Safety and security
Complementary IoT technologies	Cloud computing	Data management
		Software as a service
		Hardware as a service
		Reduce the cost of data storage
	Fog computing	Data processing close to devices
	Blockchain	Trust issues

Table 6. *Cont.*

Categories	Themes	Codes
		Improve transaction security
		Reduce potential waste
	Big Data	Prediction by big data analytics
The main phenomenon	IoT-based agricultural storage	Storage conditions
		Warehouse input-output management
		Storage procedure
		Need for quarantine
	IoT implementation	Implementation layer
		Transport layer
		Perception layer
Governance factors	Legislation	Setting legal rules
		Food safety rules
		Rules on security and operations standards
	Policy making	Supportive policies
		Policymaking about new technologies
	Organizational collaborations	Cooperation between public and private organizations
Environmental parameters	Storage conditions	Temperature
		Humidity
		Microbiology
		Warehouse pests
	Geographical factors	Weather
Consequences and results of IoT implementation	Reduce storage costs	Cost reduction due to improved storage conditions
		Reduce management costs
		Reducing labor costs
		Reduce insurance costs
		Reduce energy costs
	Improved quality control	Freshness
		Taste
		Texture
		Color
		Nutrients
	Increased revenue	Higher quality
	Improved storage monitoring	Real-time monitoring
		Safety and quality
		Transparency
	Increase customer satisfaction	Quality and safety tracking

There are different approaches to organizing and representing the outcomes of open coding. For example, not all theorists of grounded theory address features and dimensions, or researchers might define a "macro category" based on the subject of the research [80], as we did in this article. After the coding step, we translated the codes and combined different codes to form a concept or context, and then created categories and macro-categories.

The first author performed the above steps, and the results of each step were presented to the other author for verification. The other author examined the results and provided their feedback to the first author, who eventually concluded the results.

5.2.5. Quality Control

The reliability of the meta-synthesis study's output and the convergence of the extracted codes were evaluated using Cohen's Kappa coefficient in this study. Cohen's Kappa is a metric that assesses the overall agreement between two raters who categorize items into a given set of categories [81]. To accomplish this, one of the chosen articles was assigned to an expert who was requested to code it based on the research question. Then, using SPSS software, the coding results of the researchers and the expert were compared by calculating Cohen's Kappa coefficient. When the coefficient is less than 0.2, it indicates weak agreement, while moderate agreement is between 0.2 and 0.4, relatively high agreement is between 0.4 and 0.6, high agreement is between 0.6 and 0.8, and almost perfect agreement is more than 0.8 [82]. The results of the kappa coefficient calculation are displayed in Table 7.

Table 7. Comparison of Researcher and Expert Coding on a Selected Document.

Significance Level	Estimate T	Estimated Standard Deviation	Value	Degree of Cohen's Kappa Agreement
4.29	0	0.12	0.68	High

Moreover, to validate the research findings and evaluate the quality of the proposed model, eight experts were selected using the snowball method. This method, which is a kind of purposive non-probabilistic sampling, is used when it is difficult to identify members of the desired community [83]. In this method, the researcher first identifies appropriate people based on criteria such as knowledge and experience, and then, after receiving information, asks them to introduce the person or other people to them. A content analysis method was applied for receiving and analysing feedback about the conceptual model from the experts. Based on Lawshe, in the content analysis, subject experts should provide their judgment about the whole model and its constructs/components by choosing one of the following answers [84]:

1. The component use is essential.
2. The component is useful, but it is not necessary to use it.
3. It is not necessary to use the component.

To calculate the numerical mean of the judgments, the quantitative numbers 2, 1, and 0 were considered for each of the above options, respectively. Then, the content validity ratio (CVR) for each of the factors, the content validity index (CVI), and the numerical average of the judgments for each of the categories were calculated and reported using the following formula:

A: $CVR = (ne-(N/2))/(N/2)$

B: $CVI = \Sigma CVR/\text{Retained numbers}$

In Formula (A), N is the total number of experts participating in the panel, and ne is the number of experts who voted for it. Therefore, if all participants choose the first option, it will be CVR = 1, and if only half of the experts choose the first option, it will be CVR = 0. Therefore, if more than half of the participants and less than all of them choose this option, the CVR will be a number between zero and one, which is the least acceptable to confirm the content of the model according to the number of experts participating in the panel. Based on Table 8, this value will be 0.75 for 8 experts [84].

Table 8. Minimum Value of CVR and CVRt on Tailed Test, $p = 0.5$.

No. of Panelists	Min. Value	No. of Panelists	Min. Value
5	0.99	13	0.54
6	0.99	14	0.51
7	0.99	15	0.49
8	0.75	20	0.42
9	0.78	25	0.37
10	0.62	30	0.33
11	0.59	35	0.31
12	0.56	40	0.29

Therefore, if the CVR obtained for each question is equal to or higher than the minimum indicated in this table, that factor has been approved. Also, in formula (B), the content validity index is obtained from the sum of the content validity ratio divided by the number of approved items.

Following the initial revision of the model based on the experts' opinions, a questionnaire related to the final model was given to the eight experts in the fields of information technology management (Internet of Things) and supply chain management [84,85] to evaluate the validity of the final conceptual model. As discussed above, according to Lawshe [84], the minimum acceptable CVR for eight experts is 0.75. However, in cases where the CVR value was between zero and one and the average number of judgments was equal to or greater than 1.5, they were also accepted. In fact, an average of more than 1.5 indicates that more than half of the experts agree with the need for the proposed component in the IoT model. This is according to Chadwick et al. [86], who stated that a minimum value of 60% is needed for validity purposes [85]. Table 9 presents the results of evaluating the dimensions and components of the conceptual model.

Table 9. Results of evaluating the dimensions and components of the conceptual model.

Categories	Themes	Factors	Average	CVR	CVI
IoT adoption	Organizational characteristics	Organizational readiness	1.875	0.75	0.84
		Organizational Culture	2	1	
		Top Management support	2	1	
		Organization size	1.75	0.5	
		The trust	1.75	0.5	
		Skilled manpower availability	2	1	
	Environmental characteristics	External pressures	2	1	
		Government support	2	1	
		Unreliability	1.875	0.75	
		Time-to-market	1.75	0.5	

Table 9. *Cont.*

Categories	Themes	Factors	Average	CVR	CVI
IoT adoption	Financial factors	Costs saving	2	1	0.84
		Value creation	2	1	
		Implementation cost (Reverse effect)	2	1	
		High energy consumption (Reverse effect)	1.75	0.5	
		Technology cost (Reverse effect)	1.875	0.75	
		Long capital return (Reverse effect)	1.875	0.875	
	Technology features	Perceived benefits	2	1	
		Complexity	1.875	0.75	
		Adaptability	2	1	
		Technology infrastructure	2	1	
		Lack of standardization (Reverse)	1.875	0.75	
		Safety and privacy	2	1	
IoT deployment requirements	Technological requirements	IoT components	2	1	0.97
		IoT architecture	2	1	
	Implementation requirements	Budget allocation	2	1	
		Appropriate technical infrastructure	2	1	
		Stakeholder cooperation	1.875	0.75	
	Security requirements	Confidentiality	2	1	
		Authentication	2	1	
		Access control	2	1	
		Cyber attacks	2	1	
		Data security	2	1	
IoT challenges	Economic and social	Long return on investment	2	1	0.93
		Cost of use	2	1	
		Variable environment	1.75	0.5	
		Business model	2	1	
		Energy efficiency	1.875	0.75	
		Regulation	2	1	
		Staff training	2	1	
	Technological	Integration with existing ICT technology	2	1	
		Non-functional data	2	1	
		High number of required sensors	2	1	

Table 9. *Cont.*

Categories	Themes	Factors	Average	CVR	CVI
IoT challenges	Technological	Data reliability	2	1	0.93
		Standardization	2	1	
		Data scalability	2	1	
		Networking	1.875	0.75	
	Security and privacy	Safety and security	2	1	
Compleme-ntary IoT technologies	Cloud computing	Data management	2	1	0.94
		Software as a service	2	1	
		Hardware as a service	2	1	
		Reduce data storage costs	2	1	
	Fog computing	Data processing close to devices	2	1	
	Blockchain	Trust issues	2	1	
		Improve transaction security	2	1	
		Reduce potential waste	1.75	0.5	
	Big Data technology	Prediction by Big Data Analytics	2	1	
The main phenomenon	IoT-based agricultural storage	Storage conditions	2	1	0.93
		Warehouse input-output management	2	1	
		Storage procedure	2	1	
		Need for quarantine	1.75	0.5	
	IoT implementation	Implementation layer	2	1	
		Network layer	2	1	
		Perception layer	2	1	
Governance factors	Legislation	Setting legal rules	2	1	0.83
		Food safety rules	1.75	0.5	
		Rules on security and operations standards	2	1	
	Policy making	Supportive policies	2	1	
		Policy-making in the field of new technologies	2	1	
	Organizational collaborations	Cooperation between public and private organizations	1.75	0.5	
Environmental parameters	Storage conditions	Temperature	2	1	1
		Humidity	2	1	
		Microbiology	2	1	
		Warehouse pests	2	1	
	Geographical factors	Weather	2	1	

Table 9. *Cont.*

Categories	Themes	Factors	Average	CVR	CVI
IoT deployment effects	Decrease in cost	Cost reduction due to improved storage conditions	2	1	0.94
		Decrease management costs	2	1	
		Decrease labor costs	2	1	
		Decrease insurance costs	1.75	0.5	
		Decrease energy costs	1.75	0.5	
	Increase revenue	Higher price	2	1	
	Quality control optimization	Freshness	2	1	
		Taste	2	1	
		Visual quality	2	1	
		Color	2	1	
	Storage monitoring optimization	Real-time monitoring	2	1	
		Safety and quality	2	1	
		Transparency	2	1	
	Customer satisfaction	Pursue quality and safety	2	1	
	Froud-free	Following the products across the entire supply chain	2	1	
	Manual labor	Decrease the required manual labor	2	1	
	Certification	Organic products	2	1	

6. Results and Findings

The results of the meta-synthesis led to the conceptual modeling of IoT adoption in the agricultural operations through the identification of three main macro categories/constructs: IoT technology adoption (IoT implementation/deployment requirements, IoT complementary technologies, IoT implementation challenges, and IoT adoption factors); IoT-based logistics management (IoT implementation/IoT-based storage, governance factors, and environmental parameters), and the potential benefits of IoT implementation (financial, economic, operational, and social benefits/implications). These categories are discussed below.

6.1. IoT Macro Category

The results obtained from the coding of selected articles show that most of these articles addressed requirements for IoT implementation as an important feature. IoT adoption, IoT complementary technologies, and IoT implementation challenges are other subcategories related to this macro category. Figure 3, which has been obtained by MAXQDA software, represents the code theory model of the IoT macro category. This category includes IoT implementation/deployment requirements, IoT complementary technologies, IoT adoption and implementation challenges, and IoT adoption factors.

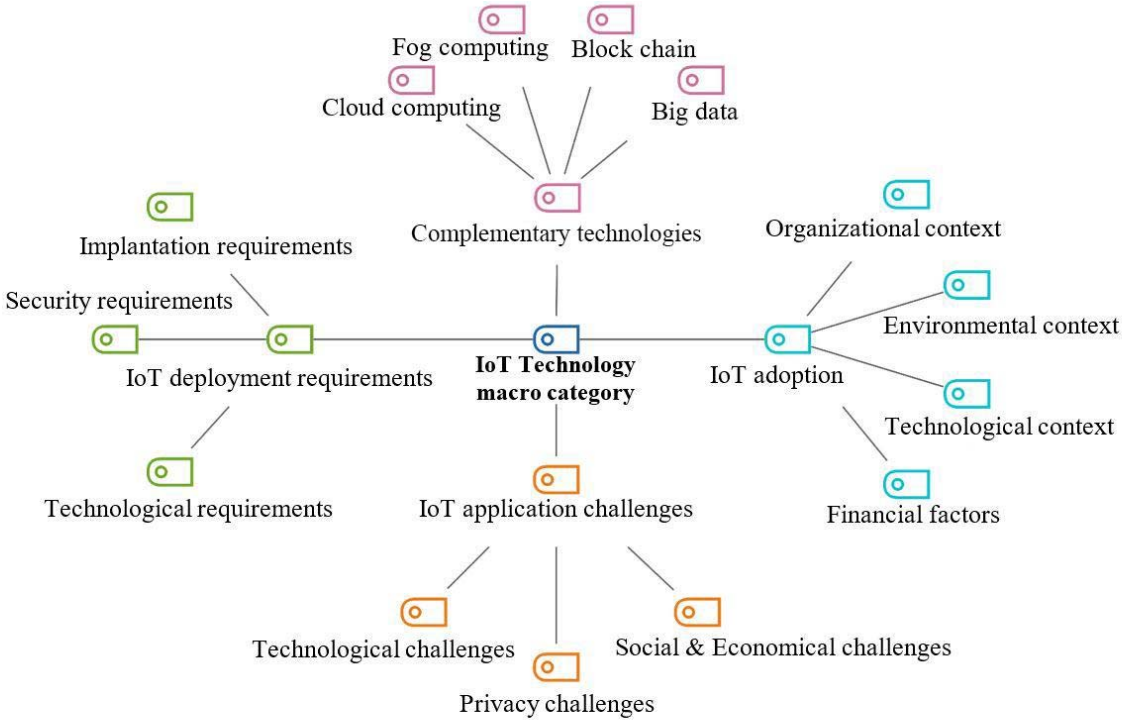

Figure 3. Code theory model of IoT technology macro category.

6.1.1. IoT Deployment Requirements

IoT implementation and deployment requirements in the context of agricultural supply chains are multifaceted and can be classified into three main categories: technological, implementation, and security requirements. Technological requirements encompass the various IoT components essential for agricultural supply chain applications, including actuators, readers, RFID technology, and wireless sensor networks. The architecture involves layers such as the implementation layer, transmission layer, and perception layer, which form the backbone of IoT infrastructure for agricultural operations [87]. These technological needs necessitate a substantial budget allocation, as creating a robust technical infrastructure tailored to agricultural environments can entail considerable investment costs. Such investments are vital for enhancing the efficiency and productivity of agricultural supply chains [87].

Moreover, IoT implementation in agricultural supply chains places a significant emphasis on security requirements due to the potential risks associated with cyber-attacks and data breaches [50,88]. Security concerns in the agricultural sector extend to three key aspects: authentication, privacy, and access control [49,89]. Research by Zhao [90] introduced a custom encapsulation mechanism known as the smart business security IoT implementation protocol, which employs cross-platform communications, encryption, digital signatures, and authentication to establish a secure communication system among various entities in the agricultural supply chain. Confidentiality and integrity concerns also find relevance in the agricultural context, as demonstrated by the work of Roman et al. [91] when exploring the applicability of key management systems (KMS) in IoT settings. KMS protocols can enhance data security and integrity in agricultural supply chain IoT applications, which are crucial for ensuring the integrity and trustworthiness of data exchanged within the supply chain [91].

6.1.2. IoT Adoption

In the realm of IoT adoption within agricultural supply chains, it's important to consider the factors influencing the acceptance and integration of this transformative technology. Drawing on the Technology, Organization, and Environment (TOE) framework, several critical elements come into play These encompass technological features, including technical adaptability and complexity, organizational factors such as the size of the agricultural organization, management support, and the existing organizational culture. Additionally, environmental factors like external competitive pressures and government support significantly impact IoT adoption [87,92,93].

Furthermore, successful adoption and integration of IoT technologies in the agricultural supply chain necessitate the support of top management to facilitate change initiatives, a finding echoed in the research of Flechsig et al. [94] and Laubengaier et al. [95]. Lack of understanding among managers about the drivers of technology adoption may hinder innovation acceptance and implementation readiness within agricultural organizations, as emphasized in the studies conducted by Ghadimi et al. [96], Flechsig et al. [94] and Stentoft et al. [97].

Cost efficiency and the value created through IoT adoption have a direct bearing on its acceptance in agricultural supply chains [98]. However, it's essential to acknowledge that factors like high implementation costs, increased energy consumption, and the time required for realizing returns on long-term investments may pose challenges to IoT adoption in agriculture [96,99].

In essence, understanding and addressing these factors are crucial for the successful deployment and adoption of IoT technologies in agricultural supply chains, ultimately contributing to enhanced efficiency, transparency, and sustainability in the sector.

6.1.3. IoT Complementary Technologies

One of the main outputs of IoT implementation is the generation of large volumes of data by Internet-connected devices. A massive increase in the amount of collected data has led to the formation of big data that is beyond the scope of conventional software tools. Therefore, the use of complementary technologies such as cloud computing, fog computing, big data analytics, and blockchain is required, along with IoT technology, to overcome data storage and analysis limitations [53,56,65,100–102].

6.1.4. IoT Adoption and Implementation Challenges

Like any innovation, the IoT faces several challenges that must be considered before adoption and implementation. Some of the most important IoT challenges can be classified into economic, social, technological, and privacy categories. Economic and social challenges include those related to the business model's compliance with industry rules and regulations, staff training, high operating costs, energy efficiency, and a lack of national or international legislation [98,103]. The most important technological challenges of IoT are those related to the integration with ICT infrastructure [104,105], including the creation of non-functional data, the high number of required sensors, data reliability, a lack of standardisation, and dealing with a large amount of data [54,87,96,98,103].

Finally, in IoT adoption, the network protocols should carefully consider security issues [106]. Organisations must consider external cyber-attacks at the perception layer, the security of data aggregation at the network layer, and authorised access to data at the implementation layer [88,101]. The most common security issues at the perception layer are considered to be information acquisition security and the physical security of the hardware.

6.2. The Main Macro Category (IoT-Based Logistics Management)

Logistics plays an important role in the storage of products in agricultural logistics operations [107]. The agricultural logistics process is becoming increasingly important due to the large amount of waste resulting from the widespread use of traditional methods in this process [108]. In this section, the most important contexts and categories related to IoT-based logistics management have been identified and presented (see Figure 4).

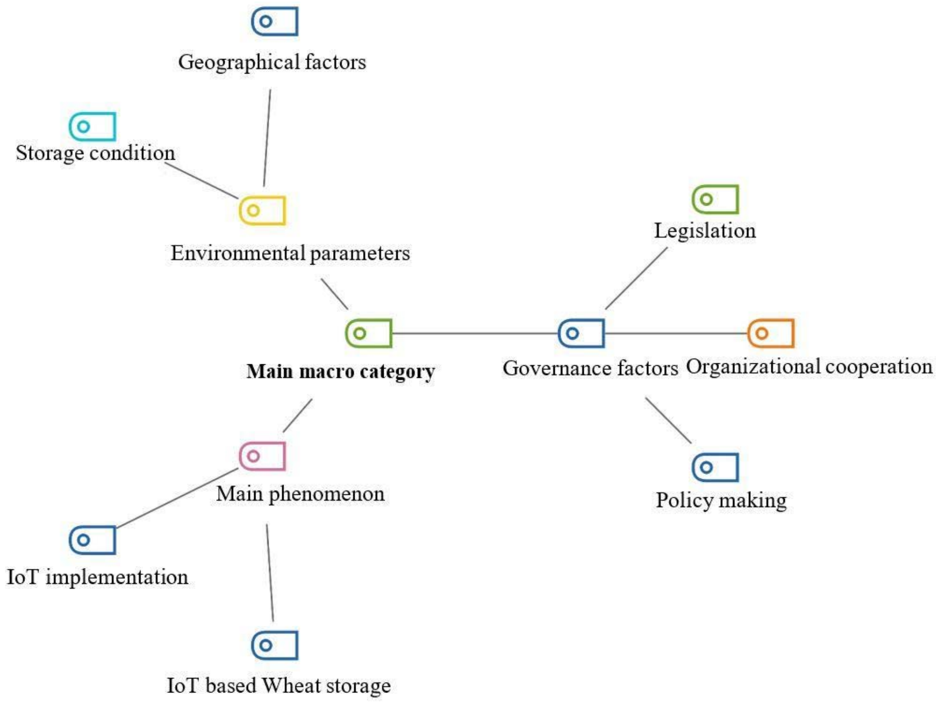

Figure 4. Code theory model of the main macro category.

6.2.1. The Main Phenomenon/IoT-Base Agricultural Logistics

IoT can help maintain the quality of agricultural products (e.g., wheat) to a large extent by improving storage conditions, warehouse entry-exit control, and storage management. Sometimes, the stored agricultural products need to be quarantined due to the prevalence and abundance of storage pests [109]. Through close and continuous monitoring [48], the IoT is able to quickly detect any pest activity and inform the need for quarantine. However, successful implementation of the IoT requires consideration of the IoT adoption structure and architecture. Xu et al. [110] argue that a sound architecture can support the "decentralised and heterogeneous" nature of the IoT. One of the most important and basic architectures presented for IoT is a three-layer architecture that is very simple and easy to implement [111]. The first layer is the perception layer, with the main task of collecting and transferring data [99]. The second layer is the network or transmission layer, which has the role of providing the possibility of secure information exchange. The third layer is the implementation layer, which is the most important layer of this technology [101], with the role of processing data and controlling a specific programme or design. Implementation architectures can significantly facilitate the process of IoT adoption and implementation.

6.2.2. Governance Factors

The IoT implementation in agricultural logistics operations requires the provision of appropriate conditions and infrastructure through legislation, policy-making, and organisational cooperation [112]. Legal information systems need to evolve to support the development and expansion of IoT in logistics management to ensure security standards and operational regulation. Furthermore, legal legislation should also specify guidelines on energy efficiency, network capacity development, and network utilisation and explicitly set bandwidth limits for sensitive frequencies [113]. Additionally, the food supply chain requires the development of integrated policies in the fields of privacy, tax exemptions, insurance, and infrastructural protections by considering the use of new technologies and information [100]. Finally, the implementation of IoT in agricultural logistics operations requires cooperation between organisations from the public and private sectors. Therefore, public and private institutions should work simultaneously to support and encourage the use of innovative and technological solutions such as IoT in agricultural logistics operations [112].

6.2.3. Environmental Parameters

According to the findings of this research, environmental parameters that should be constantly monitored are associated with storage conditions and geographical factors. Within the storage conditions, microbiology, humidity, temperature, and pests are the main parameters. The IoT provides an opportunity to increase the level of control, which leads to a better understanding of production and storage conditions such as weather conditions (temperature and humidity), microbiology, and pests [114]. Furthermore, environmental conditions widely affect food security, and any change in climate, such as rain or temperature, can affect the quality of agricultural products [35]. The implementation of IoT in the storage process of the agricultural supply chain can provide real-time and accurate monitoring of environmental parameters.

6.3. Results/IoT implementation Implications and Benefits

Finally, the last category identified is related to the results category which includes financial, economic, operational, and social benefits (Figure 5).

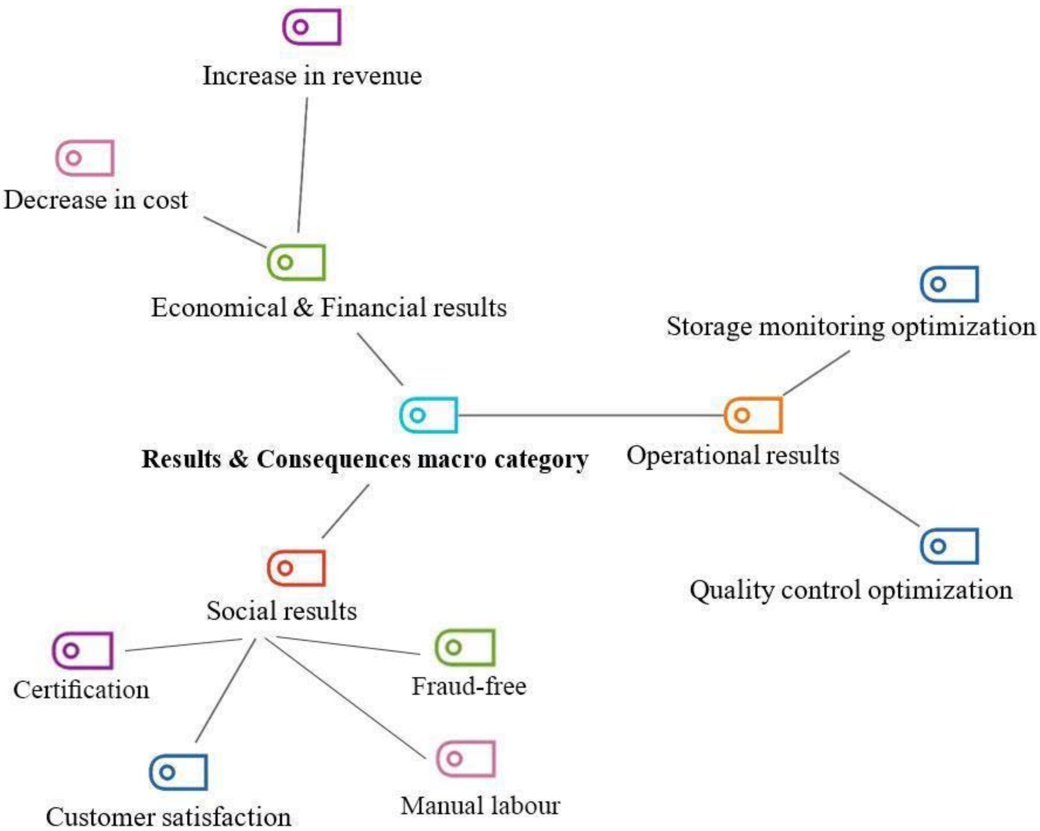

Figure 5. Code theory model of results and consequences.

6.3.1. Financial and Economic Benefits

IoT-based agricultural logistics management can significantly enhance efficiency by reducing the cost of waste and improving control over product safety, insurance, inventory, and workforce operations in logistics [52,99,115]. Similarly, improving control over logistics operations in agricultural logistics operations can lead to improved product quality. Higher-quality agricultural products command higher prices in the market, resulting in improved financial performance and increased revenue [1,102,116].

6.3.2. Operational Benefits

Based on a study conducted by [25], the most important advantages of IoT implementation in agricultural supply chains are: the transformation from passive production to active production; the possibility of outsourcing logistics to a third party, which can be a specialized logistics company; understanding the overall quality management of agricultural products; and reducing the transaction cost that occurs in the process of the circulation of agricultural products. As discussed earlier, IoT implementation in the logistics and storage processes of agricultural operations can lead to improved monitoring and quality control (freshness, taste, and nutrients) [67,117], thus preventing high costs in the waste stream by guaranteeing food safety [13,67,98,114].

6.3.3. Social Results and Consequences

IoT implementation in agricultural logistics operations enables companies to ensure the quality and safety of food via a food tracking system, which can increase customer satisfaction [7,26,118,119]. According to Lezoche et al. [120], IoT implementation in agricultural operations has some other social benefits. For example, IoT implementation could ensure that certification schemes (e.g., organic) are effective and fraud-free across the entire supply chain.

7. Meta Synthesis and Framework Development

The meta-synthesis study exploring the integration of IoT in agricultural logistics operations has produced a comprehensive framework comprising three overarching macro-categories, ten subcategories, 26 specific fields, and 89 individual codes. We delved into the intricate relationships among these categories, revealing the interconnectedness of key concepts and codes. Using network analysis, we examined the complex web of relationships that govern IoT-enabled logistics operations in agriculture. This analysis led to the development of a conceptual model, as depicted in Figure 6. In this model, categories are represented as classes, each with attributes tied to associated fields derived from relevant literature.

From this model, it's evident that successful implementation and execution of IoT technologies in agricultural logistics processes require a holistic assessment of various factors. These factors include IoT implementation requisites, the role of complementary IoT technologies, challenges in IoT adoption and execution, and key drivers of IoT adoption [16,17]. Additionally, it's essential to recognize the intricate interplay among these factors, particularly those specific to IoT-based logistics, such as IoT-based storage, governance considerations, and environmental parameters. These interrelated aspects significantly impact the overall success of IoT integration in agricultural logistics processes [18,121]. The potential benefits of IoT implementation, including financial, economic, operational, and societal advantages, hinge on optimizing resource utilization, real-time monitoring, efficient logistics management, as well as enhancing transparency and traceability [16–18].

In light of the model's insights, it's clear that a comprehensive and integrative approach is essential for IoT technology adoption. Such an approach calls for a meticulous consideration of all the aforementioned factors to ensure the successful assimilation and execution of IoT solutions in agricultural logistics operations [16–18]. This perspective aligns with the principles of the resource-based view of operational excellence, which posits that technological capabilities must yield substantial operational benefits to serve as a competitive advantage. Achieving this outcome necessitates a thorough examination of a diverse array of fundamental factors, facilitating the effective adoption and implementation of these technologies.

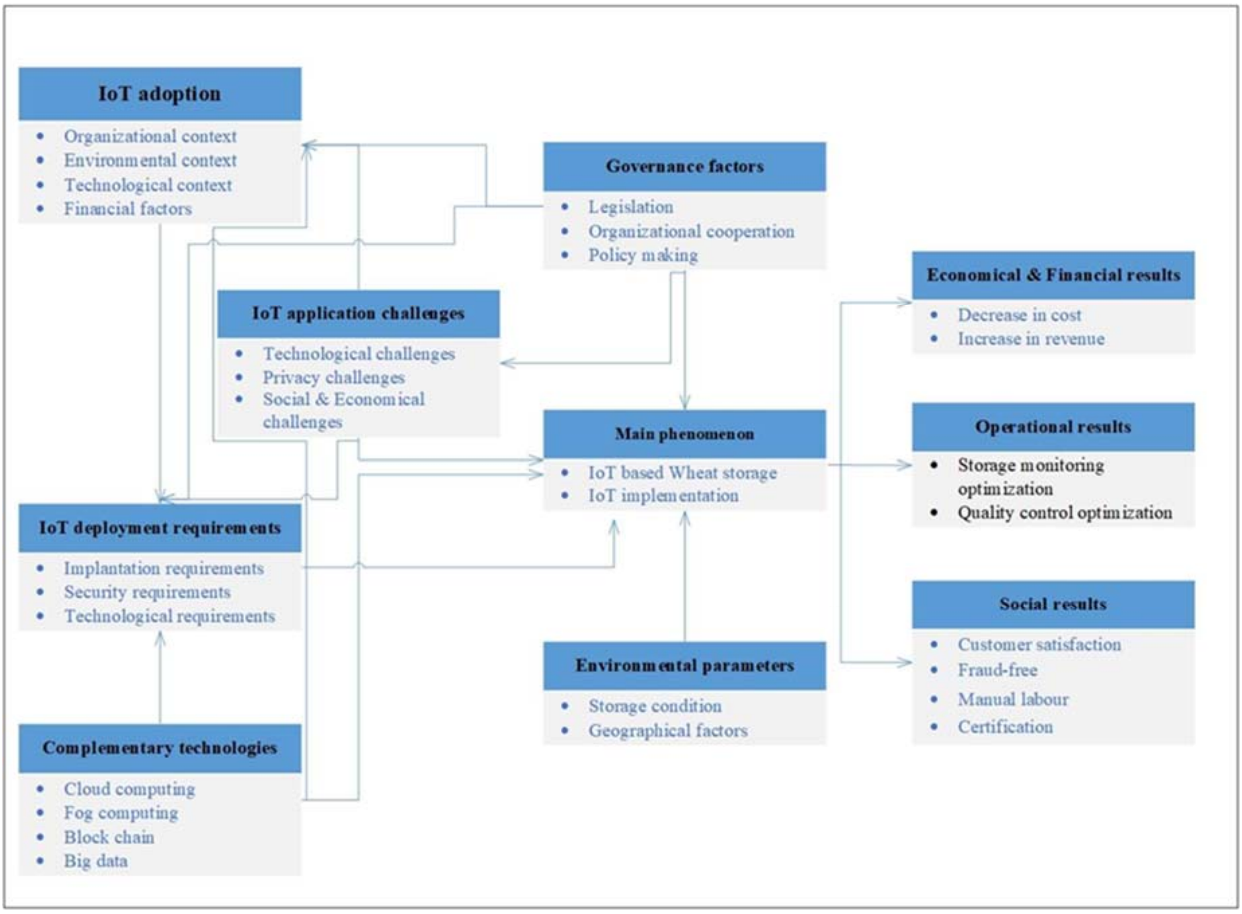

Figure 6. Conceptual model of IoT implementation in agricultural logistics operations.

8. Conclusions, Discussion and Future Research Direction

This study highlights the imperative of integrating IoT technologies into agricultural logistics operations, emphasizing the necessity for adept systems and complementary technologies. These must efficiently undertake tasks encompassing real-time information identification, collection, correlation, analysis, and distribution. Notably, our findings underscore the pivotal role of government support in ensuring the triumphant implementation of IoT in this context.

Furthermore, in light of the ongoing digital transformation reshaping societies and technological infrastructures, there exists a pressing need for updated regulatory frameworks to facilitate the seamless integration of IoT technologies. Jacobs et al. [122] aptly note this requirement. Additionally, it is crucial to establish robust legal frameworks for data protection before fostering trust in IoT infrastructure, as proposed by Taheri et al. [123] and Almeida et al. [124].

Within the sphere of agricultural logistics, it is incumbent upon managers and decision-makers to center their attention on several critical facets. These include factors influencing IoT adoption, challenges associated with its implementation, prerequisites for successful deployment, potential operational advantages, and the selection of suitable complementary technologies. A judicious consideration of IoT architecture is also pivotal during the integration process, with organizations urged to align the chosen architecture with their specific needs and circumstances. Moreover, governance elements, such as legislation, policy formulation, and organizational collaboration, wield substantial influence over IoT implementation in agricultural logistics operations. These aspects warrant dedicated attention from policymakers operating at the macro level.

To bolster the understanding of IoT adoption, future research endeavors could adopt a combination of experimental and mixed research methodologies. These approaches would facilitate an in-depth exploration of the causes behind IoT project failures and furnish practical insights for managers and decision-makers. Furthermore, given the paramount importance of real-time tracking and route optimization in agricultural logistics, a pertinent avenue of investigation would be the optimization of routes where products are dispatched to diverse destinations contingent upon their quality. Lastly, in light of the limited attention directed toward governance factors by researchers, a systematic review could be instrumental in identifying and extracting pivotal governance-related categories and dimensions within this domain.

9. Managerial Implications

The insights gleaned from the comprehensive framework and conceptual model regarding the integration of IoT in agricultural logistics operations have significant managerial implications. Agricultural logistics managers and decision-makers must recognize that the adoption and execution of IoT technologies necessitate a multifaceted approach, one that encompasses technological, organizational, and environmental considerations. First and foremost, it is imperative for managers to invest in the requisite technological infrastructure, encompassing IoT components like sensors, readers, and wireless networks. This investment needs to be aligned with the specific needs and constraints of their agricultural supply chain operations, considering factors such as farm size, the complexity of logistics, and the scale of IoT deployment [16]. Organizational factors come into play, with management support being crucial for facilitating the change required by IoT adoption. This implies a need for strong leadership and the ability to effectively communicate the value and benefits of IoT technology to the entire organization. Furthermore, fostering a culture of innovation and technological readiness is vital for ensuring the smooth assimilation of IoT solutions [17,94].

Environmental factors, including competitive pressures and government support, also require managerial attention. Managers must keep a watchful eye on the competitive landscape to leverage IoT technologies effectively. Moreover, government regulations and incentives may influence the adoption and implementation of IoT in agriculture, making it essential to stay informed about the evolving regulatory environment [87]. The managerial implications also extend to a thorough understanding of the potential challenges associated with IoT adoption, including security concerns, high implementation costs, and energy consumption. These challenges necessitate risk management strategies, cost-benefit analysis, and the exploration of energy-efficient IoT solutions [96].

In conclusion, agricultural logistics managers must take a holistic approach, addressing the technological, organizational, and environmental dimensions of IoT integration. By embracing IoT technologies with a clear understanding of these multifaceted factors, they can harness the benefits of improved resource utilization, real-time monitoring, enhanced transparency, and effective logistics management, thereby gaining a competitive edge in the agricultural supply chain [16–18].

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