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Presenting a Model for the Application of the Internet of Things in Supply Chain Management of Information Resources in Information Centers Using a Qualitative–Quantitative Approach

Sedigheh Siahsarani Salah ol Din Kola[1], Hajar Zarei [1*], Seyed Rasool Toudar[1]

1. Department of Information and Knowledge Science, To.C., Islamic Azad University, Tonekabon, Iran

*Correspondence: Hajar_zarei@iau.ac.ir

Abstract

The present study aimed to develop a model for the application of the Internet of Things (IoT) in the supply chain management of information resources in information centers. The research method was an exploratory mixed design. In the qualitative phase, participants included 15 purposively selected experts and specialists with extensive work experience and graduate-level education in management, computer science, information technology, and knowledge and information science, all affiliated with information centers and universities in Iran. In the quantitative phase, the statistical population in the first stage comprised 10 carefully selected experts participating in a fuzzy Delphi panel, chosen for their deep knowledge, broad perspective, and sufficient experience to ensure valid and reliable results. In the subsequent stage, the population included 152 employees working in information centers, electronic archives, and document and data units in Tehran. The sample size was determined using the Krejcie and Morgan table, and simple random sampling was applied. The data collection tools consisted of semi-structured interviews in the qualitative phase and a questionnaire designed based on the qualitative findings for the quantitative phase. Data analysis in the qualitative stage was performed using MAXQDA software, while the quantitative analysis employed fuzzy Delphi techniques, structural equation modeling (SEM), and the best–worst method (BWM) with the assistance of SPSS, SmartPLS, LINGO, and Excel software. From the analysis of 15 interviews, a total of 178 initial codes were extracted. After further thematic analysis, 49 basic themes and 11 organizing themes emerged. In the final stage, five overarching (global) themes were identified: procurement, production, distribution, information management throughout the supply chain, and relationship management throughout the supply chain. The quantitative results indicated that all paths between the variables were statistically significant, and all hypothesized relationships were confirmed. Furthermore, the prioritization of indicators for the IoT application model in the supply chain management of information resources in information centers revealed that "distribution" ranked first, followed by "procurement," "information management throughout the supply chain," "relationship management throughout the supply chain," and finally "production."

Keywords: Internet of Things (IoT), supply chain management, information centers

1. Introduction

The Internet of Things (IoT) has become a transformational force across multiple sectors by enabling real-time connectivity among physical objects and digital systems (Adhicandra et al., 2024). Supply chain management (SCM) is one of the domains most affected by this transformation because IoT offers unprecedented opportunities to increase transparency, responsiveness, and decision-making accuracy (Ben-Daya et al., 2017; Rebelo et al., 2022). In recent years, IoT has been recognized as a key enabler for digital supply chains, integrating sensor data, cloud platforms, and analytics to enhance end-to-end visibility (Goel et al., 2021; Rejeb et al., 2020). This capacity is especially important for information resource supply chains in knowledge-intensive organizations such as libraries, archives, and specialized information centers, where timely, accurate, and secure data flows are vital (Alagumalai & Natarajan, 2020; Ehsanian et al., 2021).

Modern organizations depend heavily on digital assets and information resources to support decision-making and service innovation. The complexity of managing these assets has increased with the expansion of distributed networks, big data analytics, and digital repositories (Jamali et al., 2019; Rajabzadeh et al., 2021). IoT provides a technological backbone to overcome such complexity by automating data collection, enabling resource traceability, and improving security across interconnected systems (Shafiq et al., 2022; Xie et al., 2019). In supply chains for information resources, IoT can track items, monitor usage, and anticipate user needs while reducing human error and operational cost (Kaladhar & Rao, 2017; Pal & A, 2020). These capabilities align with the push toward intelligent libraries and smart information environments observed in recent global research (Mirmohammadian et al., 2017; Zargari, 2019).

Despite these opportunities, many organizations—especially in developing contexts—face barriers to IoT adoption in supply chain operations. These include technical integration complexity, data privacy concerns, and insufficient managerial awareness (Sayadi et al., 2021; Zarandi et al., 2022). In the library and knowledge management sector, additional barriers arise from legacy cataloging systems, fragmented metadata standards, and budget constraints (Alagumalai & Natarajan, 2020; Zargari, 2019). Furthermore, cybersecurity and trust management remain persistent challenges because IoT ecosystems are vulnerable to unauthorized access and data tampering (CheSuh et al., 2024; Shafiq et al., 2022). Addressing these risks requires robust frameworks that combine technology readiness with governance and user-centered design (Razeghi Shendi et al., 2019; Tu, 2018).

The strategic application of IoT in SCM has been widely discussed in manufacturing, logistics, and healthcare (Hu, 2024; Rehman, 2025; Samadzad, 2024). In contrast, research on IoT-based supply chain models for information resource centers is limited (Ehsanian et al., 2021; Shambiyati et al., 2022). The information sector faces distinct supply chain challenges, such as rapidly changing digital formats, the need for secure long-term storage, and the rising demand for user-driven, personalized services (Jamali et al., 2019; Ranjbarfard & Dadashi, 2024). Recent studies show that incorporating IoT-enabled traceability and intelligent shelving can improve collection management and reduce delays in resource distribution (Afshari et al., 2017; Yousefi et al., 2023a). Similarly, smart analytics and blockchain-enhanced IoT can ensure integrity, auditability, and ethical use of sensitive information (CheSuh et al., 2024; Pal & A, 2020).

Libraries and information centers are no longer passive repositories; they are active digital platforms requiring dynamic resource flow and user interaction (Alagumalai & Natarajan, 2020; Xie et al., 2019). IoT technologies such as RFID tagging, environmental sensors, and machine learning-based predictive systems support automation of book tracking, environmental monitoring for preservation, and personalization of services (Kaladhar & Rao, 2017; Noori Hassan Abadi et al., 2020). When integrated into SCM, these technologies allow for real-time oversight of resource procurement, production (digital conversion and cataloging), distribution, information flow, and relational aspects such as user satisfaction and collaboration with suppliers (Rajabzadeh et al., 2021; Sayadi et al., 2021). Understanding how these dimensions interact is crucial for designing robust IoT-based supply chains tailored to the specific needs of information organizations (Rebelo et al., 2022; Shambiyati et al., 2022).

Scholars highlight the role of organizational capability and readiness in IoT-driven SCM (Tu, 2018; Vass et al., 2018). Effective adoption demands not only technological infrastructure but also skilled human resources, strategic alignment, and governance policies (Yousofi et al., 2023; Zarandi et al., 2022). In knowledge institutions, employee empowerment and digital literacy directly influence IoT acceptance and usage (Yousefi et al., 2023a, 2023b). Without clear training, incentive systems, and cultural support, the introduction of IoT tools can fail to deliver operational value (Afshari et al., 2017; Rajabzadeh et al., 2021). Therefore, human capital development must be part of any IoT adoption framework (Muridzi, 2024; Yousofi et al., 2023).

Another crucial factor is interoperability and integration with existing enterprise systems. The diversity of platforms in information centers—cataloging databases, digital asset management systems, cloud repositories—makes IoT integration technically demanding (Guo et al., 2018; Rejeb et al., 2020). Recent innovations, such as mobile edge computing and fog computing, provide solutions by distributing processing power closer to IoT devices, reducing latency and bandwidth costs (Adhicandra et al., 2024; Guo et al., 2018). Simultaneously, blockchain-enhanced IoT can address security and data integrity concerns while enabling trusted sharing across institutions (CheSuh et al., 2024; Pal & A, 2020). Such advancements show promise for creating scalable and secure IoT ecosystems in information supply chains (Hu, 2024; Rehman, 2025).

A review of literature also emphasizes performance measurement and decision-making quality as outcomes of IoT-based SCM (Sayadi et al., 2021; Shambiyati et al., 2022). Using IoT-generated data, managers can implement predictive analytics to optimize procurement cycles, automate replenishment, and improve vendor collaboration (Ben-Daya et al., 2017; Jamali et al., 2019). Smart dashboards and analytics allow for real-time performance tracking across key supply chain nodes (Mirmohammadian et al., 2017; Rebelo et al., 2022). For information centers, these capabilities translate into faster delivery of resources, improved user satisfaction, and cost efficiency (Ehsanian et al., 2021; Xie et al., 2019).

Yet, the contextualization of IoT-SCM models to the specific needs of Iranian information centers remains underexplored. Local studies have shown promising directions but remain fragmented (Ehsanian et al., 2021; Noori Hassan Abadi et al., 2020). Challenges include adapting global IoT frameworks to existing national standards and infrastructure limitations (Rashidi Torbati et al., 2021; Zargari, 2019). There is a need for comprehensive, evidence-based models that integrate both qualitative insights from experts and quantitative validation to ensure cultural and organizational fit (Sayadi et al., 2021; Shambiyati et al., 2022). Mixed-method research designs are particularly well-suited to bridge theoretical frameworks with practical applications in this domain (Jamali et al., 2019; Tu, 2018).

Furthermore, research in related industries suggests that robust IoT frameworks must consider sustainability and adaptability in rapidly evolving technological landscapes (Hu, 2024; Samadzad, 2024). The rise of AI-driven analytics and the convergence of IoT with big data and machine learning can increase predictive capacity and responsiveness (CheSuh et al., 2024; Safinia & Ghavami, 2024). For libraries and information centers, such intelligence can support dynamic resource allocation and adaptive user services (Adhicandra et al., 2024; Muridzi, 2024). These trends show why designing IoT-based supply chain models cannot remain static but must incorporate flexibility and resilience (Ben-Daya et al., 2017; Rehman, 2025).

Given the above context, this study seeks to fill the identified gaps by developing and empirically testing a model for the application of IoT in the supply chain management of information resources in information centers.

2. Methods and Materials

The present study employed an exploratory mixed-methods design. For this purpose, a combined (mixed) research approach was used, aiming to integrate quantitative and qualitative research methods to achieve a suitable approach for meeting the research objectives. In the qualitative stage, the researcher examined the variables, components, and categorized factors related to developing a model for the application of the Internet of Things (IoT) in the supply chain management of information resources in information centers, as derived from the theoretical foundations. Identified gaps were reviewed, those inconsistent with the subject and target population were removed, and the remaining ones were considered as the main gap factors in the domain of IoT application in supply chain management of information resources in information centers. Based on these, the interview protocol was developed. After identifying the key dimensions in the qualitative phase, they were presented to the statistical population for evaluation, and their significance was determined quantitatively. Thus, in the second phase, a "descriptive–survey" research method was applied.

Participants in the qualitative section included 15 purposively selected experts and specialists with extensive work experience and graduate education in management, computer science, information technology, and knowledge and information science, all affiliated with information centers and universities in Iran. In the quantitative section, the statistical population consisted of all managers and expert staff working in information centers, electronic archives, and document and information units in Tehran. Experts were chosen purposefully. Data saturation was reached after 12 interviews; however, to ensure greater validity, three additional interviews were conducted, resulting in a total of 15 interviews. For determining the sample size in the quantitative phase, the Krejcie and Morgan table was used, resulting in 152 respondents selected through simple random sampling.

For data collection, both library-based and field methods were used. In the library method, the literature and previous studies were analyzed using note-taking from existing documents and records. In the field method, the required data were gathered through semi-structured interviews and a researcher-designed questionnaire. Initially, the components and indicators of the IoT application model in the supply chain management of information resources in information centers were extracted through a documentary review. Subsequently, based on these findings and interview results, the researcher-designed questionnaire was developed and administered in specific Delphi rounds to collect and analyze expert opinions. In the quantitative stage, the questionnaire was employed to test and validate the proposed model and its components and indicators for IoT application in the supply chain management of information resources in information centers.

The qualitative instruments included semi-structured interviews and a review of the literature and previous research. To conduct expert interviews using the semi-structured method, Cohen and Manion's six-step model (1986) was followed. After transcribing the experts' responses, content analysis was carried out to identify both explicit and latent information. The aim of this process was to extract the components for designing the IoT application model in supply chain management of information resources in information centers. Thematic analysis was conducted using Braun and Clarke's (2006) framework. Upon completion of the qualitative stage, a 49-item researcher-designed questionnaire was created based on the identified themes and structured as close-ended questions using a five-point Likert scale. This questionnaire was then administered to managers and expert staff of information centers, electronic archives, and document units in Tehran.

For data analysis in the qualitative stage, template and thematic network analysis were performed using MAXQDA software. In the quantitative stage, to generalize the sample findings to the population, fuzzy Delphi technique, confirmatory factor analysis (CFA), and structural equation modeling (SEM) were employed with the assistance of SPSS, SmartPLS, LINGO, and Excel software.

3. Findings and Results

In the qualitative section, 15 interviews were conducted. Among the 15 participants, 80% (12 individuals) were men and 20% (3 individuals) were women. Regarding education, 53% (8 individuals) held doctoral degrees and 47% (7 individuals) held master's degrees. In terms of work experience, 7% (1 individual) had 1–10 years, 78% (11 individuals) had 11–20 years, and 20% (3 individuals) had over 20 years. Regarding age, 20% (3 individuals) were between 30–40 years, 53% (8 individuals) were between 41–50 years, and 27% (4 individuals) were 51 years and older. From the qualitative interviews, a total of 178 initial codes were extracted. After each round of analysis, code frequency and repetition were checked to confirm theoretical saturation. By interviews 13, 14, and 15, no new codes emerged, indicating that theoretical saturation was achieved, and interviews were concluded.

Subsequently, the initial codes were organized into thematic categories: 49 basic themes were derived from the 178 initial codes. These were further grouped into 11 organizing themes, and ultimately consolidated into 5 overarching (global) themes: procurement, production, distribution, information management throughout the supply chain, and relationship management throughout the supply chain.

For the fuzzy Delphi analysis, data were collected from 10 experts. The selection of Delphi panel members prioritized individuals with deep knowledge, broad perspective, and sufficient experience to ensure valid and accurate outcomes. In the first step, 49 final indicators of the IoT application model in supply chain management of information resources in information centers were structured and analyzed based on the fuzzy logic of experts' opinions using triangular fuzzy numbers. Results showed that all model factors achieved the expected importance and were accepted by experts, who reached consensus.

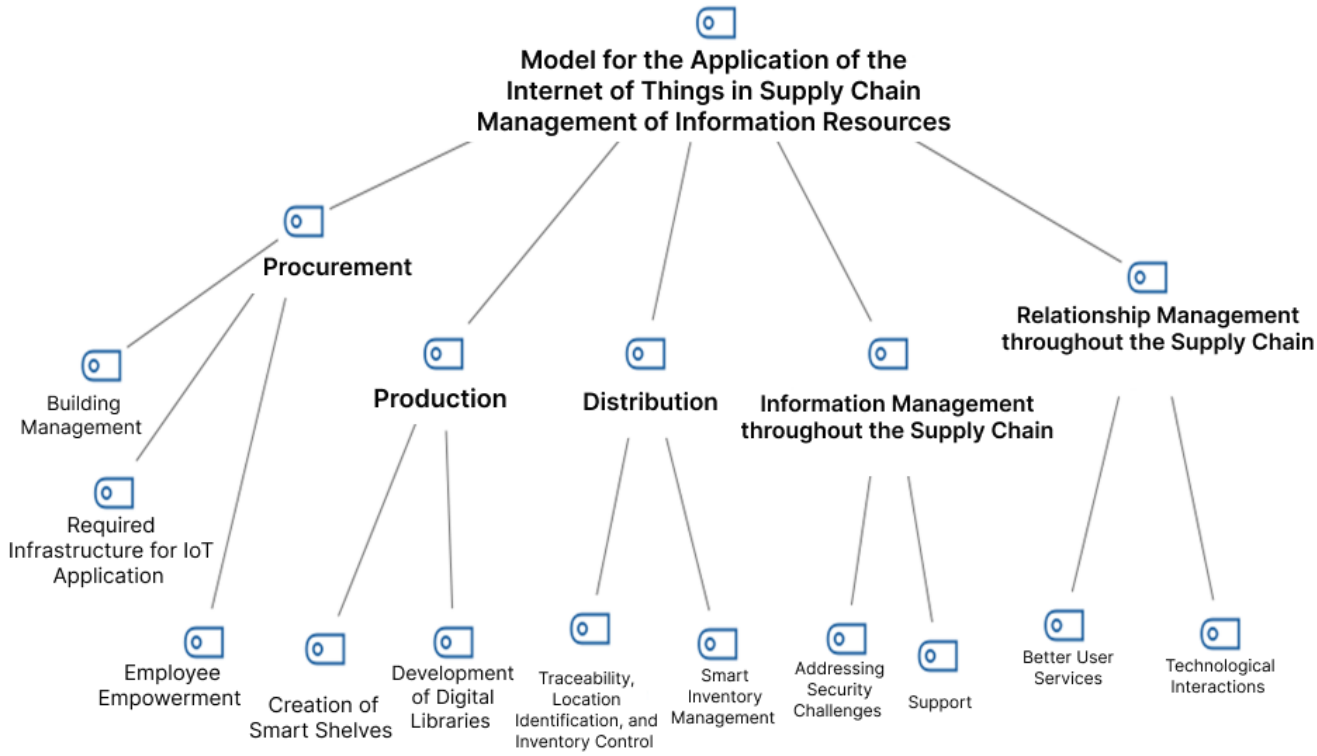

Figure 1. Conceptual Model

Table 1 presents the general demographic characteristics of the quantitative respondents, including gender, age, education, and work experience.

Table 1. Demographic Distribution of Quantitative Respondents

Percentage	Frequency
64%	97
36%	55
25%	38
48%	73
27%	41
11%	17
57%	86
32%	49

To test the normality of the data distribution, the absolute values of skewness and kurtosis should not exceed 3 and 10, respectively (Kline, 2011). Based on the results, the absolute skewness of all research variables was below 3 and the absolute kurtosis was below 10. Therefore, with 95% confidence, the data distribution can be considered normal. For implementing structural equation modeling, several approaches exist; among the most recent is the partial least squares (PLS) method. To test the conceptual model and hypotheses of this research, the PLS method was applied using SmartPLS software.

Table 2 presents the factor loadings, Average Variance Extracted (AVE), Composite Reliability (CR), and Cronbach's alpha for each construct. The reported values indicate adequate and acceptable reliability for the constructs.

Table 2. Indicators of the Studied Constructs

Dimension	Component (Latent Variable)	Indicator	Factor Loading	*t*-Statistic	AVE	CR	Cronbach's α
Procurement	Building Management	S1	0.836	23.234	0.528	0.866	0.720
		S2	0.845	21.838			
		S3	0.829	17.501			
		S4	0.901	6.147			
		S5	0.892	11.203			
	Required Infrastructure for IoT Application	S6	0.807	17.543	0.670	0.890	0.840
		S7	0.781	15.650			
		S8	0.823	20.759			
		S9	0.789	17.583			
		S10	0.801	15.258			
	Employee Empowerment	S11	0.724	11.590	0.722	0.900	0.901
		S12	0.864	9.319			
		S13	0.814	22.201			
		S14	0.872	9.781			
		S15	0.890	5.216			
Production	Creation of Smart Shelves	S1	0.832	22.487	0.668	0.824	0.931
		S2	0.859	26.070			
		S3	0.827	19.100			
		S4	0.804	3.418			
	Development of Digital Libraries	S5	0.753	12.189	0.649	0.821	0.916
		S6	0.706	11.876			
		S7	0.840	22.206			
		S8	0.827	8.437			
Distribution	Traceability, Location Identification, and Inventory Control	S1	0.751	15.495	0.671	0.900	0.940
		S2	0.918	10.878			
		S3	0.818	21.959			
		S4	0.770	14.320			
		S5	0.712	9.318			
		S6	0.930	8.011			
	Smart Inventory Management	S7	0.738	12.931	0.752	0.875	0.929
		S8	0.869	31.966			
		S9	0.922	9.331			
Information Management throughout the Supply Chain	Support	S1	0.761	13.396	0.674	0.837	0.891
		S2	0.875	28.088			
		S3	0.713	13.980			
		S4	0.753	12.451			
		S5	0.872	30.669			
	Addressing Security Challenges	S6	0.776	11.994	0.689	0.895	0.848
		S7	0.799	17.039			
		S8	0.803	20.137			
		S9	0.824	4.348			
Relationship Management throughout the Supply Chain	Technological Interactions	S1	0.900	35.465	0.748	0.889	0.860
		S2	0.727	14.791			
		S3	0.740	11.904			
		S4	0.896	38.611			
	Better User Services	S5	0.776	12.620	0.666	0.909	0.935
		S6	0.799	16.648			
		S7	0.803	20.795			
		S8	0.824	4.508			

Regarding factor loadings, since all items had loadings above 0.50, all dimensions were included in the analysis, confirming satisfactory construct reliability. The findings also showed that each construct demonstrated strong discriminant validity. Results for the second measurement criteria are also reported in Table 3 of the original article.

Table 3. Correlation Matrix and Square Root of the Average Variance Extracted (AVE) of the Variables

Relationship Management in the Supply Chain	Information Management in the Supply Chain	Distribution	Production	Procurement
				0.814
			0.879	0.111
		0.923	0.293	0.571
	0.963	0.558	0.456	0.623
0.862	0.698	0.128	0.312	0.438

According to the data in Table 3, the square root of the average variance extracted (AVE) for all variables is greater than their correlations with other variables. Thus, the Fornell–Larcker criterion for discriminant validity of the research variables is satisfied.

After establishing the measurement models to estimate the conceptual model of the research and to confirm or reject the presence of causal relationships between the study variables, as well as to assess the fit between the observed data and the conceptual model, the hypotheses were tested using structural equation modeling (SEM). The tested model is presented in Figures 2 and 3. Based on these figures, the path coefficients of all relationships are statistically significant.

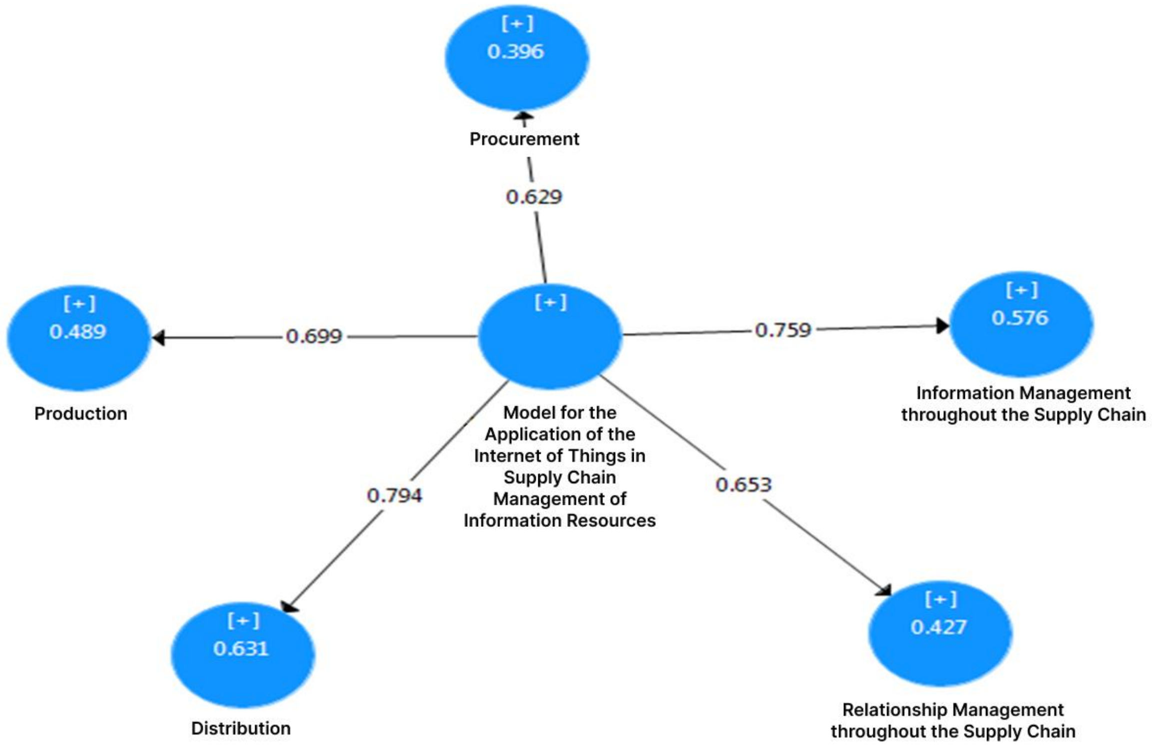

Figure 2. Measurement Model in the Standardized State

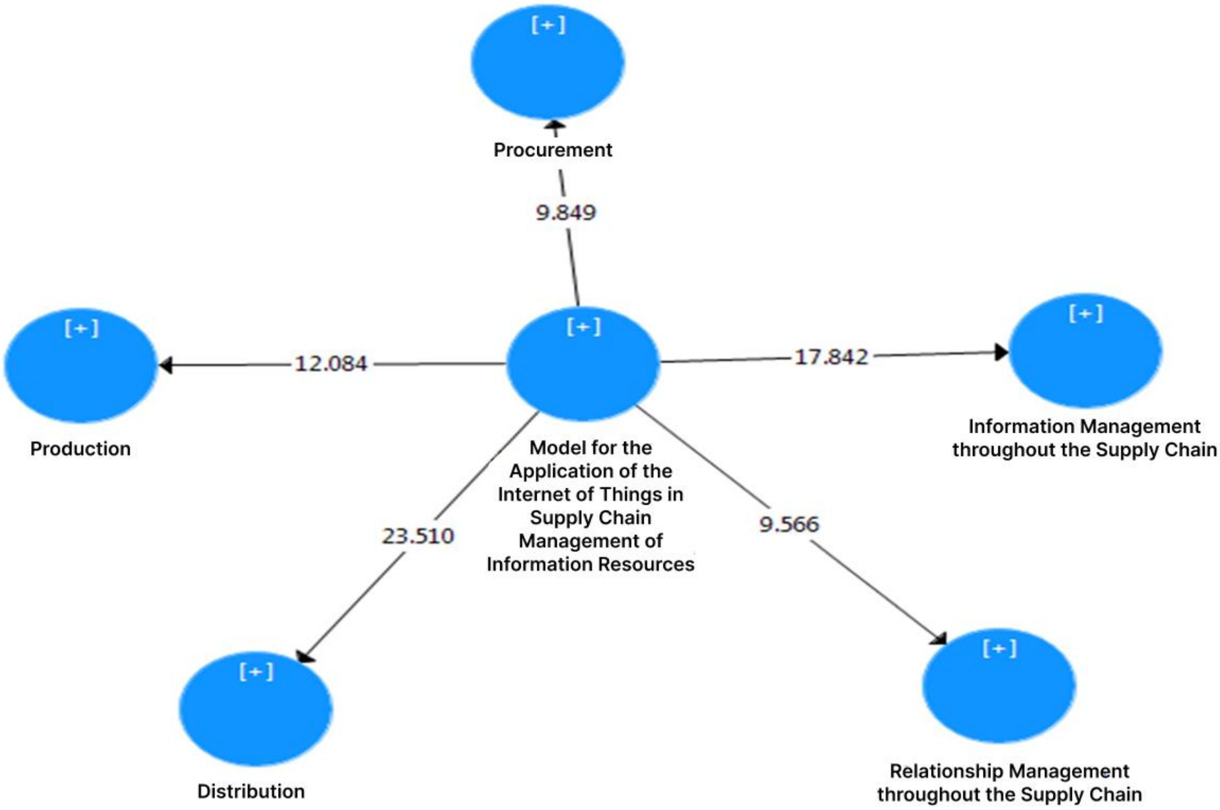

Figure 3. Measurement Model in the Significant State

At this stage, to assess the overall model fit, the Goodness-of-Fit (GOF) index, which incorporates both the measurement and structural parts, was used. Given that the coefficient of determination (R^2) was 0.540, the model demonstrates strong goodness-of-fit. In the next step, the SmartPLS software was employed to analyze the relationships among independent and dependent variables and to confirm the overall model using path analysis.

Table 4. Significance Testing of the Estimated Path Coefficients of the Research Model

Dimension	Path	Criterion	t-value	Path Coefficient	Standard Error	Significance Level	Result
IoT Application Model in Supply Chain Management of Information Resources in Information Centers	Procurement	—	9.849	0.629	0.088	0.000	Confirmed
IoT Application Model in Supply Chain Management of Information Resources in Information Centers	Production	—	12.084	0.699	0.089	0.000	Confirmed
IoT Application Model in Supply Chain Management of Information Resources in Information Centers	Distribution	—	23.510	0.794	0.099	0.000	Confirmed
IoT Application Model in Supply Chain Management of Information Resources in Information Centers	Information Management in the Supply Chain	—	17.842	0.759	0.076	0.000	Confirmed
IoT Application Model in Supply Chain Management of Information Resources in Information Centers	Relationship Management in the Supply Chain	—	9.566	0.653	0.068	0.000	Confirmed

The findings in Table 4 show that the t-values of all paths exceed 1.96, and the significance levels are below 0.05 and even 0.01. Therefore, all hypothesized relationships are supported. Additionally, the research dimensions were ranked based on the path coefficients, as shown in Table 5.

Table 5. Results of Weight Determination

Dimension Code	Dimension	Weight	Priority Rank
W1	Procurement	0.292	2
W2	Production	0.051	5
W3	Distribution	0.343	1
W4	Information Management in the Supply Chain	0.195	3
W5	Relationship Management in the Supply Chain	0.117	4

The larger the weight of a dimension, the greater its importance. In this study, the "distribution" component ranked first in the best–worst method (BWM) analysis, while the "production" component ranked fifth.

4. Discussion and Conclusion

The present study sought to design and validate a comprehensive model for the application of the Internet of Things (IoT) in the supply chain management (SCM) of information resources within information centers. The mixed-method design allowed for a deep exploration of expert insights and robust statistical validation. Five overarching dimensions—procurement, production, distribution, information management throughout the supply chain, and relationship management throughout the supply chain—were identified and confirmed through structural modeling. The results demonstrated that the hypothesized relationships among all dimensions were statistically significant, indicating the conceptual strength and practical relevance of the proposed model. Notably, "distribution" emerged as the highest-weighted dimension, followed by "procurement," "information management," "relationship management," and "production."

The prominence of distribution highlights the central role of timely and accurate movement of information resources in contemporary knowledge organizations. IoT-based traceability, inventory control, and real-time location monitoring address one of the most persistent challenges in libraries and archives: delays and inaccuracies in resource availability (Afshari et al., 2017; Jamali et al., 2019). The finding aligns with prior studies reporting that IoT-enabled logistics improve operational visibility and reduce lead times across different industries (Ben-Daya et al., 2017; Rebelo et al., 2022). In library contexts, similar technologies such as RFID and smart shelving have proven effective in optimizing circulation processes and minimizing manual errors (Kaladhar & Rao, 2017; Xie et al., 2019). By confirming distribution as the top priority, this study adds empirical evidence that IoT adoption can substantially enhance the service quality and responsiveness of information centers.

Procurement ranked second in importance, emphasizing the need for intelligent acquisition and resource planning systems. IoT-driven procurement can streamline supplier communication, automate ordering based on usage analytics, and ensure quality by integrating sensors and tracking technologies (Rajabzadeh et al., 2021; Sayadi et al., 2021). Previous work has shown that procurement decisions supported by IoT data reduce redundancies and mitigate risk in supply networks (Rejeb et al., 2020; Tu, 2018). In knowledge-intensive settings, procurement complexity is heightened by the variety of formats—digital, print, multimedia—and the need to maintain up-to-date, high-demand resources (Alagumalai & Natarajan, 2020; Ehsanian et al., 2021). Our results validate that integrating IoT into procurement enhances both cost efficiency and strategic alignment with user demand.

Information management throughout the supply chain emerged as a crucial, though slightly less dominant, dimension. IoT technologies generate vast amounts of data that, when properly processed, can inform decision-making, detect anomalies, and support predictive analytics (Adhicandra et al., 2024; Rehman, 2025). This dimension's strong significance supports previous findings that IoT transforms traditional supply chains into data-driven ecosystems capable of real-time adaptation (Goel et al., 2021; Rebelo et al., 2022). However, effective data governance and security are prerequisites. Scholars warn that IoT adoption without robust privacy and access control frameworks can expose sensitive user information (CheSuh et al., 2024; Shafiq et al., 2022). The current model's emphasis on "support" and "addressing security challenges" within this dimension responds to these concerns, echoing recommendations for secure architecture in knowledge organizations (Noori Hassan Abadi et al., 2020; Razeghi Shendi et al., 2019).

Relationship management across the supply chain, although ranked fourth, remains vital to sustained IoT adoption. Our results confirm that technological integration must be paired with strong inter-organizational collaboration and user engagement. Prior studies note that IoT success depends on building trust between suppliers, service providers, and end users, especially when data sharing and remote monitoring are involved (Muridzi, 2024; Vass et al., 2018). The presence of components such as "technological interactions" and "better user services" reflects a user-centered approach, which aligns with research emphasizing user experience as a determinant of technology acceptance (Yousefi et al., 2023a; Yousofi et al., 2023). Libraries and information centers must not only deploy devices but also manage relationships to ensure adoption and satisfaction.

Production was found to have the least weight among the five dimensions, though it remains an important enabler of digital transformation. This dimension covers creating smart shelves, converting traditional collections into digital form, and implementing IoT-ready infrastructures for content delivery (Afshari et al., 2017; Kaladhar & Rao, 2017). Its lower relative ranking may reflect the maturity of digital production processes in many information centers, where digitization and repository creation are already established (Alagumalai & Natarajan, 2020; Ehsanian et al., 2021). However, the results caution against neglecting production quality, as poorly digitized or inadequately integrated resources can hinder downstream supply chain efficiency (Jamali et al., 2019; Rajabzadeh et al., 2021).

The study's quantitative validation through structural equation modeling provides strong support for the model's reliability and convergent validity. The GOF and R^2 values confirm robust model fit, aligning with previous IoT-SCM frameworks that demonstrate how multi-dimensional constructs can be operationalized (Rebelo et al., 2022; Tu, 2018). Our findings reinforce that IoT adoption is not a single-technology intervention but a systemic transformation requiring aligned processes, governance, and infrastructure (Ben-Daya et al., 2017; Goel et al., 2021). This systemic perspective is particularly critical for information centers where traditional workflows, such as cataloging and acquisitions, interact with digital infrastructures.

Security and privacy challenges emerged as cross-cutting concerns throughout the model. This echoes global warnings about IoT vulnerabilities, including unauthorized access, malware, and data leakage (CheSuh et al., 2024; Shafiq et al., 2022). Libraries, as custodians of user data and intellectual property, must prioritize encryption, secure device authentication, and continuous monitoring (Pal & A, 2020; Razeghi Shendi et al., 2019). The inclusion of "addressing security challenges" as a distinct component under information management indicates expert consensus on integrating risk management early in IoT planning (Mirmohammadian et al., 2017; Rehman, 2025).

Another important implication relates to human resource capacity. The qualitative findings emphasized employee empowerment, training, and digital readiness as prerequisites for successful IoT integration. Prior literature supports this, showing that knowledge workers' attitudes and competencies influence technology uptake (Yousefi et al., 2023b; Yousofi et al., 2023). Cultural readiness and leadership support also determine the pace and sustainability of IoT-driven change (Rashidi Torbati et al., 2021; Zarandi et al., 2022). Our model embeds these human factors in the procurement and information management dimensions, thereby offering a more holistic roadmap than purely technical frameworks.

Finally, the study extends the understanding of IoT-enabled SCM in an Iranian context, where local infrastructure, policy environment, and institutional maturity differ from Western settings (Ehsanian et al., 2021; Noori Hassan Abadi et al., 2020). While international research provides strong conceptual grounding, local adaptation is crucial (Rajabzadeh et al., 2021; Zargari, 2019). By combining global best practices with expert insights from Iranian information centers, this model creates a culturally and operationally relevant framework that other developing nations may find adaptable (Muridzi, 2024; Samadzad, 2024).

This research faced several limitations that should be acknowledged. First, the sample size in the quantitative phase, although statistically adequate, was limited to 152 participants from Tehran-based information centers. This may affect the generalizability of the findings to other cities and to diverse types of knowledge organizations such as corporate libraries or specialized scientific repositories. Second, the study relied on expert judgment and perceptions for qualitative coding and Delphi analysis; while carefully selected, this introduces the possibility of subjectivity and contextual bias. Third, the model was validated at a specific point in time and may require adjustments as IoT technologies and standards rapidly evolve.

Additionally, budgetary and infrastructural differences across organizations could affect the applicability of the proposed framework in resource-constrained settings.

Future studies should extend this model to different organizational and cultural contexts to verify its robustness and adaptability. Cross-country comparative studies could help identify universal and context-specific factors influencing IoT adoption in information supply chains. Researchers could also explore longitudinal designs to assess how IoT maturity evolves and affects performance over time. Integrating advanced analytics such as artificial intelligence, blockchain, and edge computing into the model could offer deeper insights into emerging IoT architectures. Further investigation into user experience, including end-user trust and privacy perceptions, would provide a more human-centered understanding of IoT implementation.

Practitioners should approach IoT adoption as an integrated transformation rather than a technology upgrade. Libraries and information centers should prioritize distribution and procurement automation while maintaining strong governance over information flow and security. Investment in staff training and empowerment is crucial to ensure cultural readiness and technical competence. Managers should foster collaborative relationships across supply chain partners and embrace interoperable platforms that can scale with technological advances. Strategic alignment of IoT initiatives with organizational missions and user expectations will maximize the benefits of digital transformation in information resource management.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

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Conflict of Interest

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