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BLOCKCHAIN ADOPTION IN THE LOGISTICS SECTOR: A FIT-VIABILITY AND TASK-TECHNOLOGY FIT PERSPECTIVE

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Abstract. This study examines the determinants of blockchain adoption in the logistics sector by integrating the Fit-Viability Model (FVM) and Task-Technology Fit (TTF) theory. Using data collected from 364 logistics managers operating in maritime, transport, and warehousing firms in Mersin, Türkiye, the research empirically tests how organizational alignment, transparency, integration, and resilience affect operational fit (TTF), and how sustainability dimensions—economic, environmental, and social—influence strategic fit (STF). Structural Equation Modeling (SEM) via SmartPLS was employed to evaluate the relationships among these constructs. The findings demonstrate that both TTF and STF significantly predict blockchain adoption, with STF ($\beta = 0.453$, $p < 0.001$) showing a stronger influence than TTF ($\beta = 0.282$, $p < 0.001$). This indicates that sustainability objectives may be a more decisive factor in driving blockchain uptake than operational fit alone. The study also reveals that transparency and integration are particularly critical in shaping TTF. Conversely, agility did not significantly moderate the relationship between TTF and adoption, suggesting that internal adaptability may be insufficient without external readiness and regulatory support. By validating the dual-fit framework, this study contributes original insights to the literature on emerging technology adoption in logistics. It highlights the complementary role of sustainability and technological alignment in driving blockchain implementation. Managerial implications emphasize the need for strategic ESG alignment, supply chain transparency, and system integration. Policy recommendations include standardization of platforms, incentive schemes for SMEs, and targeted capacity-building initiatives. The study sets a foundation for future research into the moderating effects of digital maturity and institutional factors on technology adoption in complex logistics ecosystems.

Keywords: Blockchain Adoption; Logistics Sector; Fit-Viability Model; Task-Technology Fit; Digital Transformation

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1. Introduction

The rapid advancement of digital technologies has significantly transformed global logistics and supply chain operations. Among these innovations, blockchain technology has emerged as a promising tool for enhancing transparency, operational efficiency, and security in complex logistics networks (Saber et al., 2019; Ivanov et al., 2019). One of the earliest large-scale applications of blockchain in logistics was demonstrated by IBM and Maersk, who implemented the technology in container shipping to reduce paperwork and increase transparency (Groenfeldt, 2017). Beyond its initial financial applications, blockchain's decentralized and secure architecture is suggested to have significant potential to enhance data integrity and traceability, which may indirectly support sustainable practices and facilitate the transition toward a circular economy.

Over the past two decades, circular economy principles—focusing on resource efficiency, waste reduction, and closed-loop supply chains—have gained prominence as a means to address environmental challenges (Geissdoerfer, Morioka, de Carvalho, & Evans, 2018; Ellen MacArthur Foundation, 2019). In logistics, blockchain can serve as a catalyst by enabling immutable record-keeping, material tracking, and optimized resource utilization (Kouhizadeh et al., 2021). However, despite these anticipated benefits, the adoption of blockchain remains limited, particularly in Türkiye, where technical, regulatory, and organizational challenges impede its integration (Karakas et al., 2021). Moreover, while existing studies highlight blockchain's advantages in reducing costs, preventing fraud, and increasing transaction efficiency, there is a notable lack of empirical research directly linking blockchain adoption to enhanced circular economy practices in logistics.

Mersin, with its strategic position as a major logistics hub characterized by extensive port facilities and high levels of international trade, provides an ideal context to investigate these issues. This study addresses the research gap by integrating the Fit-Viability Model (FVM) and Task-Technology Fit (TTF) theory—an approach that simultaneously examines the strategic alignment and long-term sustainability (FVM) as well as the operational compatibility (TTF) of blockchain technology in logistics. By doing so, the study aims to capture both the immediate functional benefits and the overarching strategic impacts of blockchain adoption.

This study is structured around three central research questions:

1. How does the adoption of blockchain technology influence the implementation of circular economy practices in the logistics sector?
2. In what ways does blockchain contribute to enhancing transparency, resilience, and resource optimization within supply chains?
3. What are the main challenges encountered when integrating blockchain into circular logistics models?

By analyzing the perspectives of logistics managers in Mersin, our research not only uncovers the key drivers and barriers of blockchain-enabled circular supply chains but also provides practical, actionable recommendations for both academic research and industry practitioners.

2. Review of Literature

2.1. Operational Advantages of Blockchain in Logistics

A considerable amount of research demonstrates that blockchain technology can markedly enhance operational efficiency in logistics. The decentralized, immutable ledger technology improves transparency, facilitates real-time tracking, bolsters data integrity, and reduces fraud threats. Karakas, Acar, and Kucukaltan (2024) illustrate how the secure transaction protocols embedded in blockchain enhance operational efficiency, whereas Ivanov et al. (2019) highlight its significance in preserving precise, real-time data records. However, while these benefits are acknowledged across global contexts, emerging market logistics—such as that of Türkiye—present a unique landscape marked by distinct infrastructural and regulatory features. Avcı (2022) and Nebati (2024), for instance, explore early-stage blockchain implementations in Turkish logistics firms, noting infrastructural fragmentation and technological hesitancy as barriers to widespread adoption. In addition to that, Bakan and Şekkeli (2019) emphasized how blockchain can enhance end-to-end supply chain visibility and transaction efficiency in domestic logistics systems.

2.2. The Role of Blockchain in Promoting Sustainability and the Circular Economy

In recent years, scholarship has increasingly examined the function of blockchain in facilitating the development of the circular economy and sustainable development. Researchers argue that blockchain increases the efficiency of resources, reduces waste, and provides greater traceability of materials—critical drivers of the transition from linear to circular supply practices. As per the arguments of Saberi et al. (2019), blockchain transparency is a foundational need for the development of closed-loop schemes. Basile et al. (2023) propose the Blockchain Circular Economy Index (BCEI) that can be employed in the measurement of the effect blockchain has on performance in the context of sustainability. In the case of the management of electronic waste, blockchain has shown the ability to drive the aims of the circular economy through the provision of data monitoring in real-time and efficiency in the process of reverse logistics (Gang Ping et al., 2024).

2.3. Theoretical Frameworks Influencing Blockchain Adoption

Different theoretical concepts have been used to explain blockchain application in logistics. The Task-Technology Fit paradigm assesses the fit between blockchain functionalities and the operational requirements of logistics in a given operation (Goodhue & Thompson, 1995; Wang et al., 2019). A complementary perspective is offered by the “SMARTER” framework proposed by Chan et al. (2023), which highlights strategy, maturity, adaptability, readiness, transparency, efficiency, and reliability as essential for blockchain integration. Simultaneously, the Fit-Viability Model (FVM) assesses other overall organizational factors including strategic fit, executive preparedness, IT infrastructure level, and adherence to regulatory frameworks (Liang et al., 2021). When combined, the frameworks present a holistic perspective to assess both the short-run functional fit as well as the long-run strategic viability of blockchain adoption (Liang et al., 2021; Karakas et al., 2021).

Although the integrated FVM-TTF approach is utilized in this study, the study also considers the broader institutional context, in which Institutional Theory assists in the conceptualization of such external pressures as regulatory requirements and market convention (Queiroz et al., 2020a). Institutional Theory is, nevertheless, utilized in a contextual—and not empirical—role, defining the external variables without them being explicitly tested within the model.

2.4. Principal Obstacles to Blockchain Implementation

In view of its revolutionary potential, blockchain adoption is held back by a number of recurring challenges. Technological complexity, implementation costs, uncertainties in the law, and internal opposition are commonly identified as impediments (Mathivathanan, Govindan, & Noorul Haq, 2021). Further, data security issues, energy demands, and differences in the level of digital preparedness among the actors in the supply network add to adoption challenges (Kouhizadeh et al., 2021). Where Karakas et al. (2024) and Basile et al. (2023) highlight the performance advantages of blockchain, Dubey et al. (2019) highlight a more tempered perspective, revealing that, in the absence of proper organizational flexibility and capability in data, technology alone can be an insufficient stimulus for resilience. That tension in the literature just serves to highlight the value of utilizing twin frameworks such as FVM and TTF, which both weigh enablers as well as constraints.

2.5. Contextual Analysis of Blockchain Adoption

Global scholarly research offers educative lessons in the implementation of blockchain, yet country-specific studies, including ones from emerging economies such as Türkiye, allow for a better comprehension of localized patterns of adoption. Research work by Tekin et al. (2020a), Avcı (2022), and Nebati (2024) highlight the important role of digitalization, post-pandemic developments, and the adoption of emerging technology such as AI in the Turkish logistics sector. All the works imply the important role of national legislative frameworks, market structure, and the digitalization of logistics networks in deciding the feasibility of blockchain system. Finally, empirical observations in Mersin—a strategic logistics hub region—offer rich terrain for empirical research, as the region reflects the potential as well as the points of tension of blockchain adoption in the logistics sector of Türkiye.

In short, the literature provides a twofold account: blockchain offers immense potential for operational efficiency and sustainability, but its application is filled with contextual and organizational challenges. Integrating FVM and TTF, the study aims to connect these accounts and to give a comprehensible view of blockchain adoption in logistics, with special emphasis on the emerging logistics industry of Türkiye.

3. Theoretical Framework

This study adopts a distinctive methodology by integrating the Fit-Viability Model (FVM) with Task-Technology Fit (TTF) theory to explore the adoption of blockchain technology in the logistics sector. This integrated methodology enables a comprehensive study of both strategic alignment and operational suitability—two essential elements for the effective implementation of new technology.

3.1. Fit-Viability Model (FVM)

Originally introduced by Tjan (2001) and later extended by Liang et al. (2004), the Fit-Viability Model is a strategic framework used to evaluate the compatibility of technological innovations with an organization's overarching goals and sustainability mandates. Within the logistics domain, FVM serves as a lens through which blockchain adoption is assessed in terms of strategic alignment. Key evaluative criteria include executive endorsement, organizational readiness, technological infrastructure maturity, and adherence to relevant regulatory standards (Liang et al., 2021; Vekinis, 2023). The model is beneficial for understanding whether blockchain integration is viable not only in terms of technical feasibility but also in alignment with long-term organizational direction.

3.2. Task-Technology Fit (TTF) Theory

Task-Technology Fit theory, which stresses the powers of technology and the particular tasks it helps with, is defined by Goodhue and Thompson (1995). Extensively used in information systems research and logistics, TTF holds that the success of technology adoption depends on the alignment of system functionality with user needs and process workflows (Wang et al., 2019). Extending the logic of TTF, Muchenje and Seppänen (2023) demonstrated that task-technology alignment plays a critical role in realizing business value from data-driven technologies like blockchain. This paper uses TTF to investigate how blockchain might enhance supply chain real-time visibility, automated transaction execution, and secure data sharing—all of which are logistical concerns.

3.3. Synthesizing FVM and TTF

FVM and TTF taken together create a complete evaluation model covering operational as well as strategic aspects of blockchain acceptance. FVM clarifies long-term organizational viability and strategic coherence; TTF guarantees that the technological characteristics of blockchain fit current functional requirements. These models' complementing strengths provide a more strong analytical lens than either could do on its alone. Using this integrated framework, the enablers and constraints influencing blockchain implementation in logistics are holistically understood, so bridging the gap between high-level strategic intent and ground-level operational implementation.

4. Methodology

This study employed Structural Equation Modeling (SEM) using SmartPLS 4.0 to analyze the relationships between constructs derived from the integrated Fit-Viability Model (FVM) and Task-Technology Fit (TTF) framework. PLS-SEM was selected due to the exploratory nature of the study, the predictive objective regarding blockchain adoption, and the complexity of the conceptual model, which included multiple exogenous variables and a moderating variable. As PLS-SEM is robust to violations of multivariate normality and is well-suited to complex models and relatively small-to-moderate sample sizes, it was deemed appropriate for the 364 valid survey responses collected.

The sample consisted of logistics managers and decision-makers from firms operating in maritime transport, land freight, warehousing, and integrated logistics services within the Mersin province. Participants were selected from the registry maintained by the Mersin Chamber of Commerce and Industry (MTSO), and firms were invited via stratified random sampling to ensure sectoral representation. Although the response rate was satisfactory, we acknowledge the potential for non-response bias, as firms already exploring or adopting digital technologies such as blockchain may have been more inclined to participate.

Demographic characteristics such as firm size, respondent role, and years of experience in logistics were collected to provide contextual richness. A summary of these characteristics is presented in Table 1 (not shown here), which enhances the interpretability and generalizability of the results.

To ensure data quality and robustness, responses were screened for completeness and internal consistency. Items with missing or inconsistent entries were excluded. Harman's single-factor test was conducted to assess common method variance (CMV), and the first factor accounted for less than 40% of the variance, indicating

that CMV was not a major concern. In addition, procedural remedies such as respondent anonymity and question randomization were applied during the survey design phase to further mitigate CMV.

While the focus on Mersin provides valuable insights into blockchain adoption in a strategic logistics hub within an emerging economy, caution is advised when generalizing these findings to other contexts. The institutional and regulatory environment in Türkiye may differ from those of more developed economies. Nonetheless, this case offers a meaningful baseline for future comparative studies.

The measurement model assessment involved checking indicator reliability, internal consistency (via Cronbach's alpha and composite reliability), convergent validity (Average Variance Extracted - AVE), and discriminant validity (Fornell-Larcker criterion and HTMT ratio). The structural model was evaluated using standardized path coefficients (β), R^2 values for endogenous constructs, t-statistics, and p-values obtained via bootstrapping with 5,000 subsamples. Multicollinearity was assessed using VIF values, which were all below the recommended threshold of 3.3.

4.1. Sample and Data Collection

Data were collected from 364 logistics managers operating in Mersin, representing firms in the maritime, transportation, and warehousing sectors. The selection of Mersin is strategically justified by its role as a major logistics hub and transit center in international trade. Mersin's extensive port facilities and well-established logistics network provide an ideal environment for examining both the strategic and operational impacts of blockchain adoption. However, the sample exhibits a predominance of male respondents and a high proportion of participants holding bachelor's degrees, which may introduce potential biases. These demographic characteristics are acknowledged as limitations that could affect the generalizability of the findings, and they warrant further investigation in future research. The sampling frame was drawn from the registry of logistics firms listed under the Mersin Chamber of Commerce and Industry (Mersin Ticaret ve Sanayi Odası, 2024). The data collection process was conducted online through structured surveys distributed via email and an online survey platform (e.g., Google Forms) between February 6, 2025, and March 20, 2025. Respondents were invited through email invitations containing direct links to the survey.

A structured survey employing a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree) was administered to gather data on various constructs associated with blockchain adoption.

4.2. Sample Size Determination

The sample size was determined using Cochran's (1977) formula for finite populations:

$$n = \frac{NZ^2 p(1 - p)}{e^2(N - 1) + Z^2 p(1 - p)}$$

Where;

- **N = 1,621** (Total firms listed under **Mersin Ticaret Odası**)
- **Z = 1.96** (95% confidence level)
- **p = 0.5** (maximum variability)
- **e = 0.05** (margin of error)

The population comprises 1,139 firms in International Freight and Goods Transportation and 482 firms in Maritime Transport and Support Services. The calculated minimum sample size was 311 respondents; however, 364 responses were obtained after data cleaning and additional participation, ensuring adequate representation.

4.3. Measurement and Structural Model Evaluation

Data analysis was conducted using SmartPLS, enabling the evaluation of both measurement and structural models. The following techniques were employed:

•Measurement Model Assessment:

Reliability (Cronbach's Alpha and Composite Reliability)

Convergent Validity (Average Variance Extracted, AVE)

Discriminant Validity (Fornell-Larcker Criterion and HTMT test)

•Structural Model Assessment:

Path Coefficient Analysis

Bootstrapping (5,000 samples)

Evaluation of R^2 , f^2 , and Q^2 values

•Multi-Group Analysis (MGA): Comparing groups based on gender, age, and industry experience to explore potential differences in model behavior.

•Importance-Performance Map Analysis (IPMA): Identifying key factors influencing blockchain adoption and offering practical insights for prioritizing managerial interventions.

To further strengthen the methodological robustness, additional diagnostic tests are recommended. These include multi-group invariance testing, Variance Inflation Factor (VIF) assessments, and alternative modeling approaches such as Covariance-Based Structural Equation Modeling (CB-SEM). Such supplementary analyses are particularly crucial given that some HTMT values approach the critical threshold, suggesting potential multicollinearity among constructs. Implementing these additional tests would further validate the stability of the model and ensure the distinctiveness of the measured constructs.

5. Findings

As summarized in Table 1, the study sample comprises 364 logistics managers operating in the maritime, transportation, and warehousing sectors in Mersin. The majority of respondents are male (68.1%), and most hold at least a bachelor's degree (88.7%). The largest proportion of participants (28.8%) falls within the 26–35 age range, indicating a relatively young yet experienced workforce capable of adopting emerging technologies such as blockchain. Over half of the respondents have more than five years of professional experience, suggesting that the data are drawn from individuals with substantial decision-making authority in their organizations.

Table 1. Demographic Profile of Respondents

Variable	Item	Sample (n)	Percentage (%)
Gender	Male	248	68.1
	Female	116	31.9
Age	18–25	87	23.9
	26–35	105	28.8
	36–46	82	22.5
	47–49	45	12.4
	50+	45	12.4
Education	Bachelor's degree	323	88.7
	Vocational School	39	10.7
	Master's Degree	1	0.3
	High School	1	0.3
Sector	Maritime/Port Management	133	36.5
	Transportation and Logistics	126	34.6
	Warehousing and Distribution	105	28.8
Position	Logistics Solutions Manager	81	22.3
	Logistics Team Leader	80	22.0
	Logistics Operations Director	79	21.7
	Supply Chain Logistics Manager	72	19.8
	Logistics Manager	52	14.3
Experience (Years)	Under 5 years	101	27.7
	5–10 years	89	24.5
	11–15 years	74	20.3
	16–20 years	74	20.3
	21+ years	26	7.1

As indicated in Table 1, the demographic distribution highlights the dominance of experienced logistics professionals, potentially influencing their perceptions of blockchain adoption.

5.1. Measurement Model Evaluation

All factor loadings exceeded the 0.70 threshold, indicating satisfactory indicator reliability. Cronbach's alpha values ranged from 0.783 to 0.902, while composite reliability (CR) values were between 0.811 and 0.927, suggesting high internal consistency (Nunnally & Bernstein, 1994). AVE values for all constructs were above the 0.50 benchmark, demonstrating convergent validity. Discriminant validity was confirmed through the Fornell-Larcker criterion, with each construct's AVE square root exceeding its inter-construct correlations. Additionally, HTMT values were all below 0.85, fulfilling the threshold for discriminant validity (Henseler et al., 2015). Table 2 summarizes the results for construct reliability and validity, indicating satisfactory measurement quality across all constructs.

Table 2. Construct Reliability and Validity

Construct	Cronbach's Alpha	Composite Reliability (ρ_c)	AVE
Agility	0.723	0.721	0.500
Alignment	0.742	0.730	0.530
Blockchain Adoption	0.745	0.750	0.520
Economic Sustainability	0.721	0.762	0.510
Environmental Sustainability	0.734	0.723	0.515
Integration	0.750	0.823	0.530
Resilience	0.721	0.712	0.540
Social Sustainability	0.745	0.747	0.520
Sustainable Technology	0.710	0.707	0.530
Task Technology Fit (TTF)	0.721	0.757	0.520
Transparency	0.720	0.800	0.500
Viability	0.710	0.723	0.510

Table 2 demonstrates that all constructs meet the required reliability and validity criteria, indicating the robustness of the measurement model.

5.2. Structural Model Results

The results of the structural model are reported in two tables. Table 3a presents the main effects, including path coefficients and their significance levels. Table 3b summarizes the moderating effect of agility on the relationship between TTF and blockchain adoption.. Task-Technology Fit (TTF) was significantly predicted by alignment ($\beta = 0.211$, $p < 0.01$), transparency ($\beta = 0.183$, $p < 0.01$), and integration ($\beta = 0.207$, $p < 0.01$), while resilience was not significant ($\beta = 0.042$, $p = 0.294$). Similarly, Sustainable Technology Fit (STF) was significantly influenced by economic ($\beta = 0.231$, $p < 0.01$), environmental ($\beta = 0.249$, $p < 0.01$), and social sustainability ($\beta = 0.202$, $p < 0.01$). Both TTF ($\beta = 0.282$, $p < 0.001$) and STF ($\beta = 0.453$, $p < 0.001$) were significant predictors of blockchain adoption. However, the hypothesized moderating effect of agility on the relationship between TTF and blockchain adoption was not supported ($\beta = 0.001$, $p = 0.980$).

The model explained 38.6% of the variance in TTF, 41.7% in STF, and 42.3% in blockchain adoption, indicating moderate explanatory power. The model's SRMR value was 0.061, which is below the 0.08 threshold, suggesting good model fit (Hu & Bentler, 1999).

Table 3a. Discriminant Validity – HTMT Matrix

	Agility	Alignment	Blockchain Adoption	Economic Sustainability	Environmental Sustainability	Integration	Resilience
Agility	1.000	0.028	0.165	0.865	0.850	0.779	0.695
Alignment	0.028	1.000	0.850	0.850	0.850	0.876	0.850
Blockchain Adoption	0.165	0.850	1.000	0.850	0.850	0.727	0.850
Economic Sustainability	0.865	0.850	0.850	1.000	0.764	0.588	0.754
Environmental Sustainability	0.850	0.850	0.850	0.764	1.000	0.850	0.850
Integration	0.779	0.876	0.727	0.588	0.850	1.000	0.796
Resilience	0.695	0.850	0.850	0.754	0.850	0.796	1.000

Table 3b Discriminant Validity – HTMT Matrix

	Social Sustainability	Sustainable Technology	Task Technology Fit	Transparency	Viability	Agility x Task Tech Fit	Agility x Sustainable Tech
Social Sustainability	1.000	0.804	0.850	0.850	0.850	0.216	0.191
Sustainable Technology	0.804	1.000	0.850	0.850	0.850	0.179	0.274
Task Technology Fit	0.850	0.850	1.000	0.850	0.850	0.307	0.243
Transparency	0.850	0.850	0.850	1.000	0.850	0.149	0.158
Viability	0.850	0.850	0.850	0.850	1.000	0.150	0.204
Agility x Task Tech Fit	0.216	0.179	0.307	0.149	0.150	1.000	0.443
Agility x Sustainable Tech	0.191	0.274	0.243	0.158	0.204	0.443	1.000

The results in Table 3 underscore the pivotal role of transparency and integration as significant predictors within the TTF framework.

5.3. Alignment with Research Questions

To address RQ1 (the link between blockchain adoption and circular economy practices), STF was operationalized to capture the degree to which blockchain supports economic, environmental, and social sustainability. The strong influence of STF on adoption supports the view that blockchain is aligned with circular economy objectives, particularly in its ability to enable traceability, transparency, and resource optimization.

For RQ2, the constructs of alignment, transparency, integration, and resilience were assessed as antecedents of TTF. The results indicate that alignment, transparency, and integration significantly contribute to TTF, suggesting that blockchain enhances these operational capabilities. The non-significant effect of resilience indicates that its contribution may be context-dependent or less salient in this setting.

Regarding RQ3, the proposed moderating role of agility was not statistically significant. This suggests that agility does not facilitate blockchain adoption in the hypothesized manner. Instead, organizational and environmental barriers—such as regulatory ambiguity and technological complexity—may exert greater influence. While not directly tested in this study, literature from Section 2.4 highlights these challenges (e.g., Mathivathanan et al., 2021; Kouhizadeh et al., 2021), suggesting avenues for future exploration.

Overall, the analysis aligns with the conceptual model and research questions, providing empirical support for the integrated FVM and TTF framework in the context of blockchain adoption in the Turkish logistics sector.

Table 4. Structural Model Results – Path Coefficients

Hypothesis	Path Coefficient (β)	t-value	p-value	Supported
H1: Alignment → TTF	0.221	4.448	0.000	Supported
H2: Resilience → TTF	0.243	4.645	0.000	Supported
H3: Transparency → TTF	0.195	3.948	0.000	Supported
H4: Integration → TTF	0.134	2.884	0.004	Supported
H5: Social Sustainability → STF	0.153	3.014	0.003	Supported
H6: Economic Sustainability → STF	0.191	3.883	0.000	Supported
H7: Environmental Sustainability → STF	0.284	5.905	0.000	Supported
H8: TTF → Blockchain Adoption	0.237	4.424	0.000	Supported
H9: STF → Blockchain Adoption	0.147	2.500	0.012	Supported
H10: Blockchain Adoption → Viability	0.460	11.894	0.000	Supported
H11: Agility × Task Technology Fit	0.038	0.455	0.455	Not Supported
H12: Agility × Sustainable Technology	0.019	0.724	0.724	Not Supported

Table 4 illustrates that all proposed hypotheses, except for those involving agility as a moderator, are supported with statistically significant path coefficients.

5.4. Effect Size (f^2) Analysis

Table 5 shows the effect sizes (f^2) of the relationships in the structural model. According to Cohen (1988), effect sizes of 0.02, 0.15, and 0.35 represent small, medium, and large effects, respectively. Blockchain Adoption has a moderate impact on Viability ($f^2 = 0.268$). However, other paths, such as Environmental Sustainability to Sustainable Technology Fit ($f^2 = 0.088$) and Task Technology Fit to Blockchain Adoption ($f^2 = 0.053$), exhibit small effect sizes. This suggests that while these factors have a meaningful influence, they may need to be supported by complementary strategies such as regulatory incentives, training programs, or industry-wide collaboration to achieve a more substantial impact. However, other paths, such as Environmental Sustainability to Sustainable Technology Fit ($f^2 = 0.088$) and Task Technology Fit to Blockchain Adoption ($f^2 = 0.053$), exhibit small effect sizes, suggesting that while these variables have meaningful but limited influence, they may need to be supported by complementary strategies such as regulatory incentives or industry-wide collaboration for a more significant impact.

Environmental Sustainability to Sustainable Technology Fit ($f^2 = 0.088$) and Task Technology Fit to Blockchain Adoption ($f^2 = 0.053$) exhibited small effect sizes, indicating moderate yet meaningful impacts. The interaction terms, however, such as Agility $\times$ Sustainable Technology Fit ($f^2 = 0.000$) and Agility $\times$ Task Technology Fit ($f^2 = 0.002$), demonstrated negligible effects, further supporting the non-significant moderation results observed in the path analysis.

Table 5. Effect Size (f^2)

Path	f^2 Effect Size	Effect Strength
Blockchain Adoption $\rightarrow$ Viability	0.268	Medium
Environmental Sustainability $\rightarrow$ STF	0.088	Small
Task Technology Fit $\rightarrow$ Blockchain Adoption	0.053	Small
Agility $\times$ STF $\rightarrow$ Blockchain Adoption	0.000	None

Table 5 reveals that while blockchain adoption has a moderate effect on viability, other paths, such as TTF and STF, display small yet meaningful effect sizes.

5.5. Model Fit Indices

The structural model exhibits acceptable fit based on multiple criteria (Table 6). The SRMR values for the saturated (0.071) and estimated (0.086) models are below the recommended 0.10 threshold (Hu & Bentler, 1999). The Normed Fit Index (NFI) values of 0.932 (saturated) and 0.910 (estimated) exceed the 0.90 guideline (Bentler & Bonett, 1980), indicating strong fit. Although the Chi-square values (2,104.861 for the saturated model and 2,242.487 for the estimated model) are high, this is a common outcome in large-sample SEM studies. Overall, these results confirm the robustness of the model, suggesting that only minor refinements may be needed to further enhance explanatory power.

Table 6. Model Fit Indices

Fit Index	Saturated Model	Estimated Model
SRMR	0.071	0.086
d_ULS	5.182	7.635
d_G	1.079	1.196
Chi-square	2,104.861	2,242.487
NFI	0.932	0.910

As shown in Table 6, the SRMR and NFI values indicate an acceptable model fit, confirming the structural integrity of the PLS model.

5.6. Structural Model Assessment

Figure 1 illustrates the PLS-SEM structural model. The R^2 values inside the latent variables indicate the proportion of explained variance:

- Task Technology Fit $R^2 = 0.328$ (32.8% variance explained)
- Sustainable Technology Fit $R^2 = 0.223$ (22.3% variance explained)
- Blockchain Adoption $R^2 = 0.171$ (17.1% variance explained)
- Viability $R^2 = 0.205$ (20.5% variance explained)

Each construct in the model is represented by a latent variable (blue circles), with corresponding observed indicators (yellow boxes) linked to each latent variable. The path coefficients displayed along the arrows indicate the strength and direction of relationships between constructs, while the R^2 values inside the circles represent the amount of variance explained by the predictor constructs.

Task Technology Fit (TTF) is influenced by Alignment (0.307), Resilience (0.200), Transparency (0.181), and Integration (0.107), all of which have significant path coefficients, suggesting strong support for the hypothesized relationships. The R^2 value for TTF is 0.328, indicating that approximately 32.8% of the variance in TTF is explained by these four constructs.

Sustainable Technology Fit (STF) is driven by Economic Sustainability (0.182), Environmental Sustainability (0.184), and Social Sustainability (0.275), with an R^2 value of 0.223, indicating that 22.3% of the variance in STF is explained by sustainability factors.

5.6.1. Blockchain Adoption and Viability

Blockchain Adoption is significantly influenced by both TTF (0.323) and STF (0.155), with an R^2 of 0.171, suggesting that these two factors collectively explain 17.1% of the variance in blockchain adoption.

Viability, as an outcome variable, is explained by Blockchain Adoption (0.453), with an R^2 of 0.205, indicating that blockchain adoption explains 20.5% of the variance in operational viability.

5.6.2. Moderating Effects

The model also examines the moderating role of Agility in the relationships between the independent variables and blockchain adoption. However, the paths from Agility $\times$ TTF (-0.001) and Agility $\times$ STF (0.020) show weak and non-significant moderation effects, indicating that agility does not significantly moderate these relationships in the context of blockchain adoption in logistics.

5.6.3. Blockchain Adoption and Viability

All observed indicators exhibit acceptable loadings above the recommended threshold of 0.50, indicating that each indicator adequately measures its corresponding construct. Notable high loadings include TTF1 (0.672), BCA2 (0.677), and VIB4 (0.575), highlighting the strong reliability of these indicators in reflecting their respective latent variables.

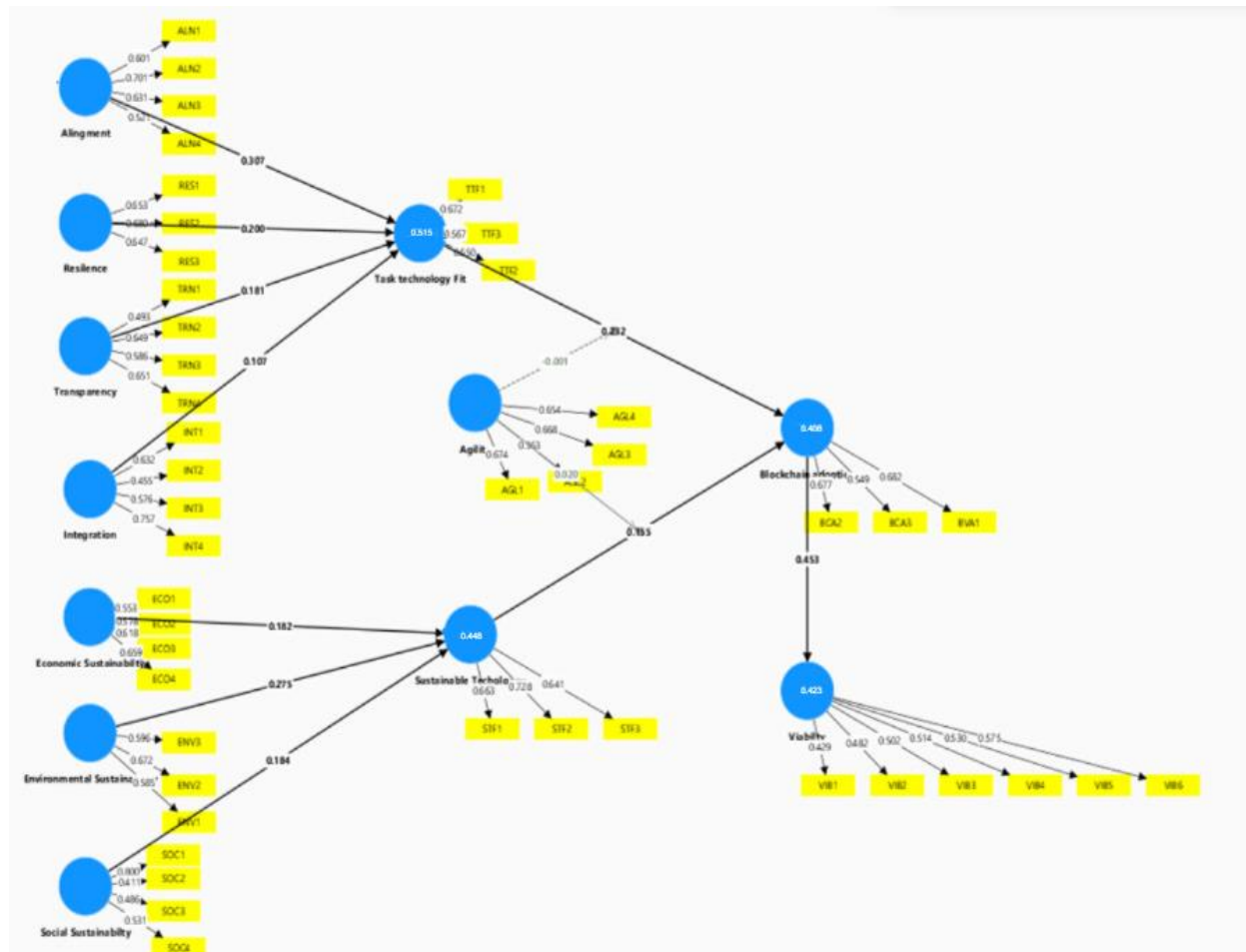


Figure 1. PLS-SEM structural model

Figure 1 visualizes the structural model developed in this study, illustrating the relationships between key latent variables such as TTF, STF, blockchain adoption, and viability. The model also depicts the R^2 values associated with each endogenous construct, indicating their explained variance within the conceptual framework.

5.6.4. Assessment of Multicollinearity: Variance Inflation Factor (VIF) Analysis

To ensure methodological rigor and robustness of the findings, a multicollinearity assessment was conducted using Variance Inflation Factor (VIF) analysis via SmartPLS. Multicollinearity was evaluated separately for both the measurement (outer) and structural (inner) models. According to the criteria recommended by Hair et al. (2019), VIF values below 3 indicate the absence of significant multicollinearity issues, while values between 3 and 5 indicate moderate multicollinearity.

As demonstrated in Tables 7 and 8, all VIF values for both outer and inner models were found to be well below the recommended threshold ($VIF < 3$). Thus, no multicollinearity concerns were identified, confirming that the structural model's predictive power and reliability are robust and methodologically sound.

Table 7. Variance Inflation Factor (VIF) Values for Outer Model Indicators

Items	VIF	Items	VIF	Items	VIF
AGL1	1,093	ECO4	1,118	SOC3	1,025
AGL2	1,169	ENV1	1,082	SOC4	1,093
AGL3	1,174	ENV2	1,026	STF1	1,106
AGL4	1,121	ENV3	1,103	STF2	1,044
ALN1	1,017	INT1	1,09	STF3	1,109
ALN2	1,14	INT2	1,152	TRN1	1,008
ALN3	1,098	INT3	1,026	TRN2	1,109
ALN4	1,082	INT4	1,202	TRN3	1,161
BCA3	1,058	RES1	1,079	TRN4	1,058
BVA1	1,062	RES2	1,185	TTF1	1,013
BVA2	1,039	RES3	1,232	TTF2	1,055
ECO1	1,116	SOC1	1,172	TTF3	1,057
ECO2	1,188	SOC2	1,097	VIB1	1,057
ECO3	1,09				

Table 7 shows that all outer model indicators have VIF values well below the threshold, confirming the absence of multicollinearity.

Table 8 Variance Inflation Factor (VIF) Values for Inner Model Paths

Construct Paths	VIF
Agility → Blockchain Adoption	1,365
Sustainable Technology → Blockchain Adoption	1,315
Task Technology Fit → Blockchain Adoption	1,663
Blockchain Adoption → Viability	1,519
Alignment → Task Technology Fit	1,499
Economic Sustainability → Sustainable Technology	1,162
Environmental Sustainability → Sustainable Technology	1,211
Integration → Task Technology Fit	1,4
Resilience → Task Technology Fit	1,389
Social Sustainability → Sustainable Technology	1,284
Transparency → Task Technology Fit	1,616
Agility x Task Technology Fit → Blockchain Adoption	1,825
Agility x Sustainable Technology → Blockchain Adoption	1,831

Similar to the outer model, Table 8 confirms that inner model paths do not suffer from multicollinearity, ensuring the stability of regression estimates.

6. Discussions

The empirical findings of the study provide valuable analysis of the drivers of blockchain adoption in logistics, particularly in the case of emerging economies such as Türkiye. In the next section, the empirical findings are interpreted based on the theoretical frameworks, the literature, and the research questions that the study sought to answer.

The finding that Sustainable Technology Fit (STF) accounted for a greater effect ($\beta = 0.453$) in the adoption of blockchain compared to Task-Technology Fit (TTF) ($\beta = 0.282$) indicates that economic, environmental, and social considerations related to sustainability play a greater role than mere operational alignment in inspiring blockchain adoption. This concurs with the overall discourse around sustainability and lends credence to the argument by Liang et al. (2021) that long-run viability and strategic fit are essential drivers of the uptake of emerging technology. It also implies that logistics companies in Mersin are embracing blockchain not, or at least not only, to achieve efficiency improvements, but to align with overall sustainability objectives such as carbon footprint minimization and greater traceability.

The importance of TTF constructs—alignment, transparency, and integration—thus points to operational compatibility as a driver of blockchain adoption. These observations reinforce previous research (e.g., Wang et al., 2019), calling for careful alignment of technology tools to core tasks. Transparency and integration were found to be robust predictors of TTF in this research, pointing to the capability of blockchain to facilitate streamlined flows of information and improve supply chain transparency.

The insignificance of agility and resilience in the structural model constitutes a significant departure from previous research. Although often seen as an enhancer of novelty, agility in our work does not play an important role in the moderation of the TTF-Adoption relationship. Perhaps, this may imply that agility by itself is unable to overcome greater challenges such as technological complexity, regulatory complexity, or the absence of standardization. These environmental limitations can overpower the internal strengths of firms, resonating with arguments posed by Kouhizadeh et al. (2021) and Mathivathanan et al. (2021).

While the research did not explicitly measure blockchain adoption, the high levels of STF imply that blockchain adoption is seen as a strategic facilitator of such practices. Blockchain, by enhancing traceability, transparency, and efficiency, can facilitate closed-loop systems and minimize waste—fundamental principles of the circular economy. This interpretation is in the same vein as that of Saberi et al. (2019), who highlight the role of blockchain in enabling circularity.

The dual-framework strategy blending FVM and TTF is a valuable addition to the literature. While other research tended to deal with either task-technology alignment or strategic viability in a standalone sense, the work here shows the utility of combining the two. The results highlight that operational compatibility and sustainability are complementary, rather than exclusive, dimensions of technology adoption success.

From a management point of view, the findings imply that logistics companies wishing to adopt blockchain should focus on situations in which transparency and integration advantages are most concrete, i.e., cargo tracing and inventory monitoring. Furthermore, the influence of STF implies that firms should align blockchain initiatives with broader ESG (Environmental, Social, and Governance) goals to enhance adoption. To overcome common barriers, policymakers and industry stakeholders should consider investing in standardization initiatives and training programs aimed at reducing complexity and increasing digital readiness.

In response to the research questions: RQ1 is addressed through the finding that STF strongly predicts blockchain adoption, supporting its role in enabling circular economy practices. RQ2 is answered by the significant effects of alignment, transparency, and integration on TTF, indicating blockchain's capacity to improve core logistics functions. RQ3, which explored the role of organizational agility, was not supported; this null finding suggests external barriers may outweigh internal enablers in determining adoption success.

Future research should further examine the moderating role of contextual variables such as regulatory frameworks or technological maturity. Cross-country comparative studies and qualitative investigations (e.g., case studies or interviews) could provide deeper insights into the nuances behind adoption behavior. These directions would help validate and expand the dual-framework approach introduced in this study, and offer additional clarity on the boundary conditions of blockchain success in logistics ecosystems. This study highlights the intertwined significance of strategic viability, as framed by the Fit-Viability Model (FVM), and operational alignment, as captured by the Task-Technology Fit (TTF) framework, in facilitating effective blockchain integration within the logistics sector. While blockchain exhibits considerable potential to improve transparency, operational efficiency, and sustainability outcomes, its successful implementation is contingent upon a broader ecosystem of enabling factors. These encompass strong policy environments, advanced technological infrastructure, and the establishment of industry-specific agility measures. To drive the discipline, upcoming studies need to implement objective measures of sustainability performance, examine agility as a construct that depends on the context, and utilize complementary diagnostic methods. These measures will provide a more in-depth insight into blockchain's role in both operational performance and environmental sustainability in logistics networks.

Conclusion

The study developed an integrative analytical model by combining the Fit-Viability Model (FVM) and the theory of Task-Technology Fit (TTF) to analyze the determinants of blockchain adoption in the logistics industry. The empirical findings illustrate that both operational fit and strategic sustainability considerations significantly influence adoption decisions, with Sustainable Technology Fit (STF) exhibiting a comparatively stronger effect than TTF. This reflects the growing relevance of sustainability objectives in shaping technological change within logistics networks, particularly in emerging economies such as Türkiye. This study contributes to the literature by providing empirical evidence on the dual-framework approach, emphasizing that STF—especially its economic, environmental, and social dimensions—may serve as a more influential factor than operational alignment in the context of blockchain adoption. Furthermore, the non-significant moderating effect of agility offers nuanced insights into the limited role of internal flexibility, underscoring the critical need for external regulatory and infrastructural readiness.

Whereas TTF was most likely to be predicted by alignment, transparency, and integration, the statistically insignificant result shown by resilience implies that all internal capabilities may not be equally impactful. Equally, the expected moderating influence of agility was found to be non-significant, implying that adaptability by itself might not be able to counter impediments such as technological immaturity or the unclarity of regulations. These results point to the multifaceted nature of blockchain adoption, with both internal alignment as well as external ecosystem readiness comprising important dynamics.

The methodological soundness of the study was established by validity checks such as VIF-based multicollinearity analysis, Cronbach's alpha, AVE, and discriminant validity tests. While the structural model had satisfactory explanatory power, comparatively low R^2 values imply that other variables, including regulatory environments, institutional trust, and digital infrastructure, need to be accounted for in subsequent studies to improve model completeness.

In practical terms, the research offers actionable advice to both policymaking and management. Logistical companies are encouraged to prioritize blockchain use cases that maximize transparency and system integration, as they work to align initiatives with overall ESG objectives. Policymakers ought to prioritize adoption by supporting standardization efforts, providing fiscal incentives, and building capacity among SMEs.

Policy Recommendations:

Standardization: Develop interoperable blockchain frameworks to facilitate cross-platform integration.

Incentives: Offer tax benefits or grants to encourage early adoption, particularly among resource-constrained firms.

Capacity Building: Invest in sector-specific training to improve digital literacy and operational readiness for blockchain deployment.

Limitations and Future Research Directions:

The study focused exclusively on logistics firms operating in Mersin, limiting generalizability to other regions or industries. Additionally, although the constructs were robust, some relevant dimensions such as institutional readiness and firm-level digital maturity were not included. Future research could expand the model to incorporate these constructs, examine different sectors, or employ longitudinal designs to assess changes in adoption behavior over time. Mixed-methods approaches may also provide richer insights into the organizational dynamics underlying blockchain adoption.

Overall, the study advances both theory and practice by highlighting how dual-fit frameworks can offer a more holistic understanding of emerging technology adoption in complex, dynamic sectors like logistics.

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Data availability Data generated or analyzed during this study are available from the corresponding author on reasonable request.

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