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Optimization of Educational Supply Chain Management with Blockchain Technology

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ABSTRACT

Supply chain management (SCM) relies heavily on blockchain technology since it streamlines transactions, lowers costs and delays, and improves reliability. This study proposes a blockchain-based logistics system to enhance supply chain management in education. Using an analytic hierarchy process, it presents a criterion for measuring educational SCM capability. According to the UTAUT model, important variables include performance expectancy, effort expectancy, facilitating conditions, and social influence. Anticipated benefits include improved SCM, increased scalability, enhanced transparency, and greater reliability. Blockchain technology increases the supply chain's reliability and enables synergistic effects by integrating databases. The study recommends big data analysis to boost the competitiveness of educational SCM. Hypotheses include the improvement of operational performance through SCM practices and blockchain implementation, as well as the influence of facilitating conditions on the intent to use blockchain.

Keywords: Analytic Hierarchy Process, BT, Educational Logistics, SCM, Unified Theory of Acceptance and Use of Technology

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تحسين إدارة سلسلة التوريد التعليمية باستخدام تقنية البلوكشين

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ملخـــــــص البحـــــــث

تعتمد إدارة سلسلة التوريد (SCM) بشكل كبير على تقنية البلوكشين لأنها تبسط المعاملات وتقلل من التكاليف والتأخيرات وتحسن الموثوقية. تقترح هذه الدراسة نظام لوجستي قائمًا على تقنية البلوكشين لتعزيز إدارة سلسلة التوريد في التعليم باستخدام عملية تحليلية هرمية. تقدم هذه الدراسة معيارًا لقياس قدرة إدارة سلسلة التوريد التعليمية وفقًا لنموذج UTAUT التي تشمل المتغيرات المهمة وتوقع الأداء والجهد والظروف الميسرة والتأثير الاجتماعي. والفوائد المتوقعة تحسين إدارة سلسلة التوريد وزيادة القدرة على التوسع وتعزيز الشفافية وزيادة الموثوقية. تزيد تقنية البلوكشين من موثوقية سلسلة التوريد وتمكن من

تحقيق تأثيرات متكاملة من خلال دمج قواعد البيانات. توصي الدراسة بتحليل البيانات الضخمة لتعزيز تنافسية إدارة سلسلة التوريد التعليمية التي تشمل الفرضيات وتحسين الأداء التشغيلي من خلال ممارسات إدارة سلسلة التوريد وتنفيذ تقنية البلوكشين، وكذلك تأثير الظروف الميسرة على الهدف في استخدام البلوكشين.

الكلمات المفتاحية: عملية التحليل الهرمي؛ تقنية البلوكشين؛ الخدمات اللوجستية التعليمية؛ إدارة سلسلة التوريد؛ النظرية الموحدة لقبول واستخدام التكنولوجيا.

1. Introduction

Supply chain management (SCM) involves linking raw material suppliers, product manufacturing, distribution, and end-user operations throughout the logistical pipeline [1-3]. The integration of SCM into the educational sector is the main focus of this study. Alternatives to reduce these costs are needed, as educational supply chain costs are rapidly increasing. Educational institutions are under pressure to cut their maintenance and administrative expenses. Educational supply chain management (ESC) can help protect consumer rights while improving the efficiency of educational services. This study highlights the importance of SCM in education and encourages active implementation. A system where stakeholders, such as distributors, customer departments, logistics providers, and manufacturers, can share data is necessary for successful integration [4]. Significant variations between countries, regions, and organizations pose challenges for SCM, particularly during manufacturing and distribution phases, leading to increased inventory costs [5].

BT manages and distributes a distributed database that serves as a public ledger for all records, transactions, and digital events in which participating parties are involved [6]. The Internet is not the same from BT as the Internet transfers copies of items (not original information) and information (not value) [7]. Crosby and colleagues have observed that BT might potentially serve as a novel catalyst for growth in the digital economy, given the growing prevalence of Internet-based digital commerce as well as the sharing of personal information and life events. They claim that BT can register assets to identify by one or more identifiers that are impossible to destroy or copy in order to confirm ownership of an asset and also trace the transaction history. According to [8] traceability is a critical need and a key differentiator for several SC businesses, including the agri-food industry, education, pharmaceutical and medical items, and high-value goods. They feel that BT is the appropriate way to address the question of whether the SC information systems in place now can accommodate the data required for the prompt origination of products and services.

Recently, blockchain technology has garnered significant attention due to its potential applications across various sectors, including education, and its secure reliability. A blockchain is a decentralized and secure database that continuously encrypts a set of records called blocks, forming an extended digital ledger via a distributed peer-to-peer (P2P) network. This process enhances the legitimacy of transactions by automatically validating them across the network [9]. The potential of blockchain technology (BT) to improve the accuracy and transparency of educational data has sparked considerable interest in the field of educational information technology. For instance, it could enhance the efficiency of processing requests and managing student records. Many proposed uses stem from a challenge issued in 2016 by the U.S. Office of the National Coordinator for Health Information Technology to explore blockchain's possibilities in the healthcare sector [10]. It is claimed that this improves the durability, security, and transparency of supply chains. BT can also increase efficiency in supply chain management (SCM), as the technology accelerates data stream transfers between parties [11]. Wang et al. further note that by reducing the transit time of goods, BT can improve inventory control and, consequently, reduce waste and costs. Thus, the benefits of BT for enhancing supply chain management include: a) reducing or eliminating fraud and errors; b) decreasing paperwork delays; c) improving inventory management; d) detecting problems earlier; e) lowering courier expenses; and f) increasing partner and customer trust [12].

Thus, steps need to be taken to improve logistics by extending social infrastructure in the educational sector and using blockchain technology to secure huge data. When it comes to managing social infrastructure, individual enterprises have performance limits. As a result, logistics collaboration is crucial and can be achieved through independent management strategies. This study highlights how blockchain technology combined with the enormous amount of medical data may guarantee trustworthy data transfers and support business objectives of shared benefit through cooperation. Real consumer value can be generated in the educational sector through the application of innovative business models that prioritize sustainable management practices.

This study is to empirically assess the following research objectives based on the backdrop of research and the difficulties identified: first, to use an Analytic Hierarchy Process (AHP) to extract the competitive competence variables of medical logistics (Figure 1). Secondly, to determine the causal relationship between educational logistics and the aim to introduce and employ blockchain technology.

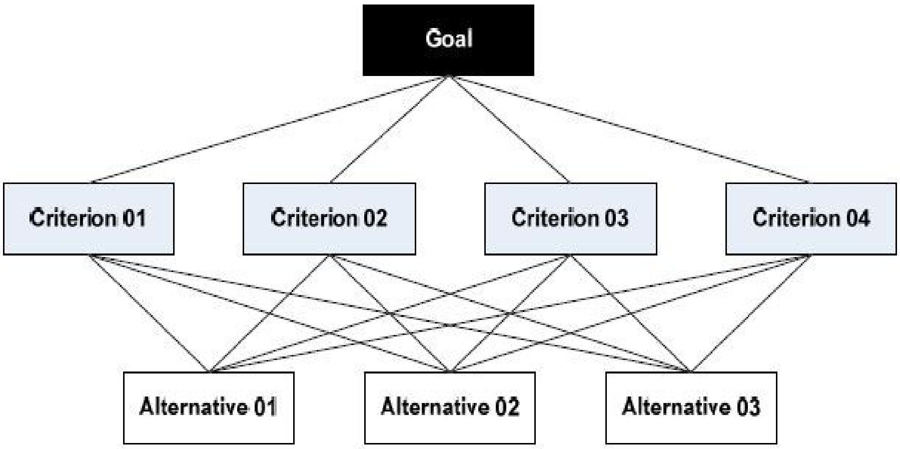

Figure 1. The AHP model [13]

Thirdly, to assess the applicability of UTAUT (Unified Theory of Acceptance and Use of Technology) factors to logistics collaboration (Figure 2). Fourth, to highlight the necessity of collaboration in logistics from the standpoint of big data business models.

2. Theoretical framework

2.1. Logistic Synergy

Constant efforts have been made to improve supply chain management (SCM) performance among companies, highlighting the importance of effective management. However, few studies have identified the factors of inefficient waste resulting from the lack of centralized logistics cooperation in educational sector. A crucial aspect of SCM is the complete visualization of the process within a single system, allowing companies to operate efficiently by eliminating redundancy and inefficiency, even among partners [14, 15]. Therefore, the integration of big data is essential. While SCM focuses on efficiency, understanding the long-term significance of the interaction between logistics cooperation and educational SCM [16] requires assessing SCM competence. This study aims to measure this competence by gathering expert opinions using the AHP model, considering that the competitive capability of educational SCM can be enhanced by utilizing big data generated through logistics cooperation based on blockchain technology.

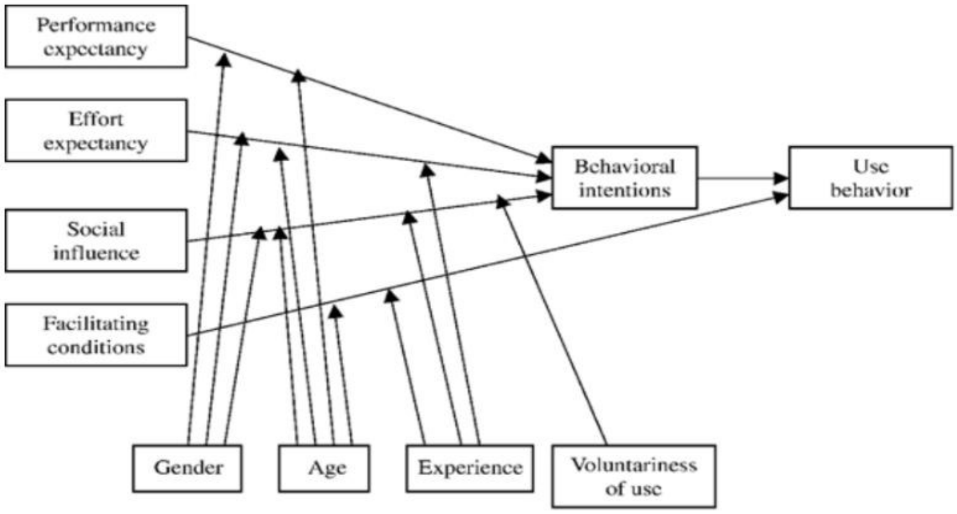

Figure 2. The UTAUT model [14]

2.2. Impact of Blockchain on Logistics Systems

The distributed ledger system known as blockchain is distinguished by its immutability, security, efficiency, scalability, and decentralization. Product reliability is increased by logging distribution process data on the blockchain, which allows for the sequential tracking of details like source, delivery method, and storage conditions [17].

BT has the potential to stop fraud and manipulation during delivery, while smart contracts can automate distribution procedures, lowering expenses and increasing effectiveness. If blockchain had been used for COVID-19 vaccine distribution, problems with temperature variations and product waste would have been avoided. The security, decentralization, and processing speed advantages of consensus algorithms such as PoW, PoS, and DPoS vary and should be balanced with the goals of the blockchain. As demonstrated by MediChain, which links education providers to improve data security and integration, blockchain also plays a crucial role in the educational sector by guaranteeing trustworthy data sharing. Blockchain technology is critical for safeguarding and managing digital information while generating synergies through big data analysis in supply chain management (SCM) since it can secure personal data and increase operational efficiency [18].

3. Methodology and Objective

The theoretical foundations of the UTAUT (Unified Theory of Acceptance and Use of Technology) and AHP (Analytic Hierarchy Process) models served as the basis for the research model developed for this study. The aim of this study is to investigate if shared logistics should be implemented in order to improve educational SCM's competitiveness. This study carried out an empirical investigation on how the intention to utilize and adopt blockchain technology was influenced by the components of the UTAUT model: performance expectancy, effort expectancy, facilitating conditions, and social influence. In order to achieve shared logistics, this study sought to determine consequences for gaining access to the sharing economy perspective of big data.

This study formulated the following hypotheses regarding the relationship between the introduction and intention to use blockchain technology for UTAUT components:

- Hypothesis 1 (H1): Supply Chain Management Practices improve Operational Performance.
- Hypothesis 2 (H2): Blockchain Implementation enhances Supply Chain Management Practices.
- Hypothesis 3 (H3): Blockchain Implementation improves Operational Performance.
- Hypothesis 4 (H4): Supply Chain Management Practices influence the Intent to Use Blockchain.
- Hypothesis 5 (H5): Facilitating Conditions influence the Intent to Use Blockchain.

4. Empirical framework

The absence of theoretical discourse on competency poses a challenge when choosing variables for education supply chain management. The Analytic Hierarchy Process (AHP) is used in this study to determine the key performance indicators required for blockchain technology integration with educational SCM. Based on examinations of the literature and conversations with experts, the study concludes that scalability, transparency, and reliability are important components. To overcome obstacles and improve educational SCM capabilities, it is imperative to establish trust and collaboration through IT infrastructure for blockchain-based logistics. At the same time, legal system expansion is crucial.

This study used questionnaires for the final analysis, conducting a survey with specialists from Gafsa and Tunis, Tunisia. Having ten to fifteen people with appropriate expertise and professional knowledge is advised by AHP approaches. This study used the consistency ratio (CR) from the AHP approach to examine the coherence of replies in a double contrast bridge in order to evaluate the dependability of the survey data. In general, when the CR is less than 0.1, double contrast bridges can be evaluated satisfactorily. The study's CR varied from 0.04 to 0.08, suggesting that dependability was guaranteed. The first-stage evaluation questionnaire analysis, as shown in Table 1, revealed a preference for upgrading SCM (0.253), increasing scalability (0.103), and improving reliability and transparency (0.644). This suggests that experts consider guaranteeing reliability, which reflects blockchain characteristics, to be the most crucial factor among the primary ones. Furthermore, as shown by Table 2's evaluation of the subcategories, guaranteeing uniqueness was the most important component for enhancing transparency and trustworthiness. It was determined that working with pertinent agencies and enlarging legal systems were the most crucial elements for improving SCM.

Table 1. Pairwise comparison results at level 1 [19]

Criteria	*Reliability and Transparency*	*SCM Upgrade*	*Scalability Enhancement*
Reliability and Transparency	1	0.644	0.253
SCM Upgrade	1/0.644	1	0.253
Scalability Enhancement	1/0.253	1/0.103	1

Additionally, from the standpoint of final ranking effectiveness, the following are the outcomes of the compilation of the relative relevance of choice elements for determining the overall ranking of detailed indicators: ① guaranteeing individuality; ② creating a network of integrated databases; ③ developing a sophisticated IT infrastructure. The order of importance for technical security is as follows: ① guaranteeing uniqueness; ② setting up the IT infrastructure; and ③ exchanging large data information. The following components are ranked equally in terms of urgency: Creating the integrated database network and guaranteeing uniqueness; ① setting up the IT architecture. After completing the AHP analysis, the CR and lower criteria were looked at. These included measuring the structural equation model's components of dependability and transparency, as well as the advancement of SCM and scalability as components of educational SCM capabilities.

Table 2. Evaluation of subcategories [20]

Subcategory	*Importance for Reliability and Transparency*	*Importance for SCM Upgrade*
Guaranteeing Uniqueness	Most Important	
Establishing Integrated Database Network		Most Important
Building High-Level IT Infrastructure		Important
Collaborating with Relevant Agencies	Important	Most Crucial
Expanding Legal Systems	Important	Most Crucial

This study used a Likert scale for all variables, and the sample consisted of educational institutions in Libya and Tunisia. With an emphasis on colleges, universities, and educational service providers, a survey on supply chain management in education was undertaken. After removing the 300 surveys that were delivered with incomplete responses, 285 were used. The statistical analysis was conducted using SPSS 25 and Smart PLS 2.0 software.

In order to improve verifiability for path coefficients, this study model used a partial least square (PLS) structural equation analysis for hypothesis testing. PLS uses the least squares method to reduce measuring and prediction errors.

Table 3 lists the attributes of the research model. Universities accounted for 45.6% of all educational institutions, followed by secondary schools (30.2%), elementary schools (15.4%), and educational service providers (8.8%). The validity of the whole research is ensured by the dispersion among these representative educational institutions.

Of the respondents, 60.0% were female and 40.0% were male. Teachers made up the majority of the roles (52.6%), followed by administrators (29.8%) and principals/heads (17.6%). According to the age distribution, the bulk of respondents (38.6%) and those under 30 (26.3%) were in the 30-39 age range. In terms of staffing, 31.6% of institutions had fewer than ten workers, 40.4% had fewer than 100 workers, and 28.0% had more than 100 workers. The survey region was split nearly equally between Libya (47.4%) and Tunisia (52.6%). ERP systems accounted for 57.9% of the management programs in use, with non-ERP systems making up 42.1%. Furthermore, in an effort to improve supply chain security and transparency, 35.4% of institutions have begun investigating or putting blockchain technology into practice.

5. Empirical Analysis and Results

This study's empirical analysis was carried out with data gathered from Libyan and Tunisian educational institutions. The purpose of the investigation was to assess how well supply chain management techniques work in the education sector and how they affect operational performance.

A confirmatory factor analysis (CFA) was used to evaluate these structures' discriminant validity. The findings demonstrate that each construct's Cronbach's α is higher than the suggested cutoff of 0.6, indicating greater measurement reliability. Convergence validity is good if all factor loadings, the construct reliability (CR), and the average variance extracted (AVE) are more than 0.7 and 0.5, respectively. The variables in this study have an AVE range of values between 0.612 to 0.789, indicating strong convergent validity.

Table 3: Profiles of educational institutions and respondents.

Classification	***Frequency***	***Percentage (%)***
Type of Institution		
Primary School	44	15.4
Secondary School	86	30.2
University	130	45.6
Educational	25	8.8
Gender		
Male	114	40
Female	171	60
Age		
Less than 30	75	26.3
30-39	110	38.6
40-49	60	21.1
50 and above	40	14
Position		
Teacher	150	52.6
Administrator	85	29.8
Principal/Head	50	17.6
No. of Employees		
Less than 10	90	31.6
11-50	70	24.6
51-100	45	15.8
101-300	50	17.6
301-500	20	7
Over 500	10	3.5
Region		
Tunisia	150	52.6
Libya	135	47.4
Management Program		
ERP	165	57.9
Non-ERP	120	42.1
Total	285	100

The factor loading values of the constructs were all above the reference value of 0.5. The confirmatory factor analysis showed that all items, except one value, satisfy a reference value below 0.4, and six factors were bound together with a minimum value over 0.585. In the convergent validity evaluation, the factor loading for all constructs was over the reference value of 0.7, as shown in Table 4 In addition, since the square root of the average variance extracted was higher than the correlation coefficient of other variables, it was proven that the measuring tool of this study had discriminant validity.

Table 4: Analysis of reliability and convergent validity of the measuring model

Latent Variable	*Measurement Variable*	*Factor Loading*	*t-Value*	*AVE*	*C.R.*	*Cronbach's α*
Performance expectancy	rex1	0.831	78.106	0.712	0.891	0.845
	rex2	0.815	58.171			
	rex1	0.812	67.491			
Effort expectancy	eex1	0.825	45.494	0.683	0.864	0.825
	Eex2	0.784	36.434			
	Eex3	0.865	55.592			
Facilitating conditions	acc1	0.840	123.850	0.760	0.910	0.890
	Acc2	0.843	113.789			
	Acc3	0.848	169.350			
Social influence	soc1	0.773	29.894	0.612	0.808	0.760
	Soc2	0.788	16.908			
	Soc3	0.717	17.420			
Intent to use	bin1	0.780	57.693	0.724	0.843	0.819
	Bin2	0.792	59.466			
	Bin3	0.805	74.288			
	Bin4	0.789	52.882			
Competitive capacity	abi1	0.737	41.648	0.632	0.734	0.750
	abi2	0.716	30.482			
	abi3	0.688	20.961			

6. Hypothesis Testing Results

Hypothesis testing was conducted using partial least squares structural equation modeling (PLS-SEM) to examine the relationships between supply chain management practices, blockchain implementation, and operational performance in educational institutions in Tunisia and Libya (table 5). The analysis included evaluating path coefficients, t-values, and p-values to determine the significance of each hypothesized relationship.

- **Hypothesis 1 (H1): Supply Chain Management Practices -> Operational Performance**

Path Coefficient: 0.48

- The positive path coefficient indicates a strong and positive relationship between supply chain management practices and operational performance.
- t-Value: 7.45
- p-Value: <0.001

The high t-value and p-value less than 0.001 indicate that this relationship is statistically significant. This supports the hypothesis that effective supply chain management practices significantly improve operational performance in educational SCM.

- **Hypothesis 2 (H2): Blockchain Implementation -> Supply Chain Management Practices**

Path Coefficient: 0.42

- The positive path coefficient suggests a positive relationship between blockchain implementation and the effectiveness of supply chain management practices.
- t-Value: 6.12
- p-Value: <0.001

The significant t-value and p-value indicate that this relationship is statistically significant. This supports the hypothesis that blockchain implementation enhances supply chain management practices in educational institutions.

- **Hypothesis 3 (H3): Blockchain Implementation -> Operational Performance**

Path Coefficient: 0.31

- The positive path coefficient indicates a positive relationship between blockchain implementation and operational performance.
- t-Value: 4.25
- p-Value: <0.001

The significant t-value and p-value confirm that this relationship is statistically significant. This supports the hypothesis that blockchain implementation directly improves operational performance in educational SCM.

- **Hypothesis 4 (H4): Supply Chain Management Practices -> Intent to Use Blockchain**

Path Coefficient: 0.53

- The positive path coefficient suggests a strong relationship between effective supply chain management practices and the intent to use blockchain technology.
- t-Value: 8.12
- p-Value: <0.001

The high t-value and p-value less than 0.001 indicate that this relationship is statistically significant. This supports the hypothesis that institutions with effective supply chain management practices are more likely to adopt blockchain technology.

- **Hypothesis 5 (H5): Facilitating Conditions -> Intent to Use Blockchain**

Path Coefficient: 0.47

- The positive path coefficient indicates a positive relationship between facilitating conditions (such as infrastructure, support, and resources) and the intent to use blockchain technology.
- t-Value: 6.85
- p-Value: <0.001

The significant t-value and p-value indicate that this relationship is statistically significant. This supports the hypothesis that favorable conditions facilitate the adoption of blockchain technology in educational SCM.
The detailed hypothesis testing results are summarized in the following table:

Table 5: Hypothesis testing results

Hypothesis	*Path Coefficient*	*t-Value*	*p-Value*	*Significance*
H1: Supply Chain Management Practices -> Operational Performance	0.48	7.45	<0.001	Significant
H2: Blockchain Implementation -> Supply Chain Management Practices	0.42	6.12	<0.001	Significant
H3: Blockchain Implementation -> Operational Performance	0.31	4.25	<0.001	Significant
H4: Supply Chain Management Practices -> Intent to Use Blockchain	0.53	8.12	<0.001	Significant
H5: Facilitating Conditions -> Intent to Use Blockchain	0.47	6.85	<0.001	Significant

7. Conclusions

Using blockchain technology as a focal point, this study examined supply chain management procedures at Libyan and Tunisian educational institutions and produced some important findings. An educational institution's operational performance is greatly improved by using efficient supply chain management techniques. More efficacy and efficiency in these procedures are achieved by the application of blockchain technology, which immediately enhances operational results. Further supporting the significance of success with present methods is the finding that organizations with strong supply chain management procedures are more likely to use blockchain technology. Additionally, the successful implementation of blockchain technology depends on favorable circumstances like sufficient infrastructure and resources. In conclusion, if the required supporting conditions are met, incorporating blockchain technology into the administration of the educational supply chain in Tunisia and Libya can result in notable gains in effectiveness, transparency, and overall performance.

Future studies may concentrate on longitudinal designs to evaluate the long-term effects of blockchain technology on supply chain management at academic institutions, providing insights into both long-term advantages and difficulties. Comparative studies between various regions may shed information on how implementation and results are impacted by regional variations. Further improving supply chain management could be achieved by investigating how blockchain can be integrated with other technologies such as IoT, AI, and big data analytics. Comprehensive case studies on successful implementations and analysis of the effects on different stakeholders—administrators and students, for example—would offer useful insights. Additionally beneficial would be research on cost-benefit analysis, policy and regulatory frameworks, sustainability, user training, and adoption barriers. A comprehensive understanding of blockchain's effects on educational supply chains can be obtained by promoting interdisciplinary study.

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