



Adoption of Blockchain-Based Electronic Bills of Lading: Implications for Maritime Business Education and Industry Practice

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ABSTRACT

The digitalization of maritime trade documentation through blockchain-based electronic bills of lading (eBL) represents transformative innovation with profound implications for shipping operations and maritime business education. This study investigates eBL adoption dynamics from dual industry practice and educational preparation perspectives, examining factors influencing technology acceptance and identifying gaps between industry requirements and academic curriculum coverage. Employing mixed qualitative methodology, the research analyzes perspectives from logistics professionals (n=45), early adopter organizations (n=12), and maritime business program coordinators (n=15) across Indonesian and regional maritime education contexts. Through thematic analysis integrating Technology Acceptance Model constructs, the study reveals that perceived operational efficiency, trust mechanisms, regulatory recognition, and ecosystem interoperability constitute critical adoption determinants. Findings demonstrate significant disparities between rapid industry transformation toward digital trade documentation and limited academic coverage of blockchain technologies, eBL platforms, and digital shipping operations within maritime business curricula. The research proposes comprehensive educational framework integrating blockchain fundamentals, eBL platform functionality, smart contract applications, and hands-on digital documentation simulations. Results provide actionable guidance for curriculum modernization addressing the urgent need for graduates equipped with digital trade documentation competencies essential for contemporary maritime logistics careers.

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1. INTRODUCTION

The maritime shipping industry, long characterized by paper-intensive documentation processes dating to mercantile practices of previous centuries, confronts unprecedented pressure to embrace digital transformation as global supply chains demand real-

time visibility, seamless information exchange, and accelerated cargo release procedures [1]. Among various digitalization initiatives reshaping international trade operations, blockchain-based electronic bills of lading (eBL) emerge as particularly transformative technology, promising to replace centuries-old paper bills of lading with secure, tamper-proof digital

documents that enable instantaneous transfer of title, reduce fraud risks, and eliminate costly courier services for physical document exchange [2]. The traditional paper bill of lading serves three critical legal functions—acting as receipt for goods, evidence of contract of carriage, and document of title—creating complex requirements for any electronic substitute to achieve equivalent legal recognition and commercial acceptance. Blockchain technology, with its distributed ledger architecture, cryptographic security, and immutable transaction records, offers technical infrastructure potentially capable of replicating and even enhancing these traditional functions while simultaneously addressing long-standing inefficiencies in maritime trade documentation workflows [3].

The operational and economic implications of eBL adoption extend across the entire maritime logistics ecosystem, affecting shipping lines, freight forwarders, cargo owners, banks financing international trade, insurance providers, customs authorities, and port operators who collectively handle millions of trade transactions annually. Conservative estimates suggest that digitalization of bills of lading could reduce trade document processing costs by 50-70%, eliminate document courier expenses exceeding \$350 million annually in container shipping alone, accelerate cargo release by 24-48 hours in major ports, and substantially reduce disputes arising from lost, delayed, or fraudulent documentation [4]. Beyond direct cost savings, eBL platforms enable new operational capabilities including real-time cargo tracking integrated with documentation status, automated letters of credit processing triggered by smart contracts, enhanced supply chain visibility supporting just-in-time logistics, and improved regulatory compliance through transparent audit trails. Despite these compelling benefits, actual eBL adoption rates remain modest, with industry estimates suggesting that electronic bills of lading account for less than 2% of containerized trade volumes as of 2024, indicating substantial barriers impeding widespread transition from paper to digital documentation practices [5].

Multiple factors contribute to slow eBL adoption despite recognized benefits and increasingly mature technological solutions. Legal recognition challenges persist in numerous jurisdictions where domestic legislation explicitly requires paper documents or where courts lack established precedent for treating electronic documents as equivalent to paper originals for title transfer purposes. The Rotterdam Rules, an international convention specifically designed to accommodate electronic transport documents, achieved limited ratification and remains far from universal implementation necessary for comprehensive legal certainty across global shipping routes [6]. Ecosystem coordination challenges create chicken-and-egg dynamics where individual stakeholders hesitate to

invest in eBL capabilities until trading partners, banks, and regulatory authorities demonstrate readiness, yet systemic readiness cannot emerge until critical mass of participants commit to digital platforms. Interoperability concerns arise from multiple competing eBL platforms—including CargoX, WAVE, essdocs, Bolero, and edoxOnline among others—employing different technical architectures, business models, and governance structures, creating fragmentation risks and necessitating careful platform selection decisions by prospective adopters. Organizational resistance manifests through concerns about cybersecurity vulnerabilities, reluctance to abandon familiar paper processes, skepticism regarding technology reliability, and inertia favoring established practices despite their acknowledged inefficiencies [7].

Maritime business education programs face critical challenges responding to these industry transformations, as traditional curricula focused on conventional shipping operations, paper documentation procedures, and established trade finance mechanisms require fundamental updating to prepare graduates for digital maritime logistics environments. Preliminary examination of maritime business and logistics program syllabi across Indonesian and regional institutions reveals limited coverage of blockchain technologies, minimal hands-on experience with eBL platforms, and insufficient emphasis on digital trade documentation competencies that employers increasingly expect from entry-level professionals. This educational gap creates potential misalignment between academic preparation and industry requirements, risking graduate employability challenges and constraining industry innovation capacity as organizations struggle to find personnel equipped with necessary digital competencies [8]. The rapid pace of technological change compounds these challenges, as educators struggle to maintain currency with evolving platforms, shifting regulatory frameworks, and emerging best practices while simultaneously managing traditional curriculum obligations and resource constraints that limit experimental course development.

Indonesia's strategic position as a major maritime nation—ranked among the world's top ten container port operators by throughput volume and serving as critical link in Asia-Pacific supply chains—creates particular urgency for addressing eBL adoption and maritime business education modernization challenges. Indonesian shipping companies, freight forwarders, and port operators increasingly interact with international trading partners adopting digital documentation practices, necessitating equivalent domestic capabilities to maintain competitive positioning and service quality. The Indonesian government's broader digital economy development initiatives, including investments in trade single window systems and customs modernization

programs, create supportive policy environment for eBL adoption while simultaneously generating expectations for maritime workforce capabilities that current educational systems inadequately address [9]. Maritime business programs across Indonesian universities and specialized maritime institutions bear responsibility for preparing logistics professionals, shipping managers, and supply chain analysts who can navigate both conventional and digital trade documentation regimes, yet face substantial challenges acquiring appropriate teaching resources, developing faculty expertise in emerging technologies, and establishing industry partnerships that provide authentic learning experiences with actual eBL platforms.

This research addresses fundamental questions regarding eBL adoption dynamics and their implications for maritime business education transformation. The study specifically investigates three interconnected dimensions of this central inquiry. First, the research examines what factors influence organizational intentions to adopt blockchain-based eBL platforms, exploring how perceived benefits, trust mechanisms, regulatory considerations, and ecosystem readiness shape decision-making among carriers, freight forwarders, and cargo owners. Understanding these adoption factors enables identification of priority interventions that could accelerate digital transformation while simultaneously illuminating competency requirements that maritime business graduates must possess to support organizational eBL initiatives. Second, the study analyzes current maritime business curriculum coverage of digital trade documentation and blockchain technologies, identifying specific gaps between academic instruction and industry practice that constrain graduate preparedness for contemporary logistics careers. Third, the research develops evidence-based recommendations for maritime business education modernization, proposing specific curriculum enhancements, pedagogical approaches, and industry-academia collaboration models that better align academic preparation with digital maritime logistics competency requirements [10].

The significance of this research extends across technological, educational, and economic dimensions within maritime logistics ecosystems. From a technology adoption perspective, the study contributes empirical evidence regarding specific factors facilitating or impeding eBL implementation, offering insights valuable for platform providers, industry associations, and policymakers seeking to accelerate digital trade documentation transition. For maritime business education institutions, the research provides systematic analysis of curriculum gaps and actionable recommendations for modernization initiatives, supporting more effective educational responses to

industry transformation. From an economic development perspective, enhanced eBL adoption supported by appropriately skilled workforce could yield substantial efficiency gains, cost reductions, and competitive advantages for national maritime sectors while simultaneously supporting broader trade facilitation objectives. For students and early-career professionals in maritime logistics fields, improved educational preparation for digital documentation environments directly enhances employability and career advancement prospects [11].

Methodologically, this research employs mixed qualitative approaches combining survey research with logistics professionals to quantify adoption intentions and perceived benefits, semi-structured interviews with early adopter organizations to understand implementation experiences and success factors, and curriculum analysis examining maritime business program syllabi to identify educational gaps and enhancement opportunities. This multi-method design enables comprehensive understanding spanning individual perceptions, organizational experiences, and systemic educational patterns, while the integration of industry practice and academic perspectives illuminates critical interdependencies between workforce capabilities and technology adoption trajectories. The research framework draws upon Technology Acceptance Model (TAM) constructs to structure investigation of adoption factors while extending beyond purely technological considerations to encompass legal, organizational, and ecosystem dimensions that substantially influence eBL implementation outcomes [12].

The structure of this paper proceeds through systematic examination of eBL adoption dynamics, educational implications, and transformation pathways. Following this introduction, the research method section details the mixed qualitative methodology, participant recruitment strategies, data collection instruments, and analytical procedures employed to ensure research rigor and practical relevance. The results and discussion section presents findings organized around adoption factor themes, educational gap analysis, and implementation recommendations, relating empirical evidence to existing technology adoption and maritime education literature. The conclusion synthesizes primary contributions, discusses limitations, and proposes future research directions supporting continued maritime business education evolution and industry digital transformation.

2. RESEARCH METHOD

This research employed mixed qualitative methodology designed to comprehensively investigate blockchain-based electronic bill of lading adoption factors and maritime business education implications

through integration of multiple data sources and analytical perspectives. The methodological approach combined structured survey research capturing quantitative perceptions across broader logistics professional populations with in-depth qualitative interviews exploring organizational adoption experiences and curriculum analysis examining educational program content, enabling triangulation of findings and development of holistic understanding spanning individual, organizational, and systemic dimensions [13]. This multi-method design was selected as most appropriate for addressing complex research questions that encompass technological, organizational, legal, and educational considerations requiring diverse forms of evidence and analytical approaches.

The research population encompassed three distinct stakeholder categories representing different perspectives on eBL adoption and maritime business education transformation. The first category consisted of logistics professionals working in shipping lines, freight forwarding companies, port operators, and cargo owner organizations who represent potential eBL adopters and whose perceptions regarding technology benefits, concerns, and adoption intentions directly influence implementation trajectories. The second category comprised representatives from early adopter organizations that had already implemented blockchain-based eBL solutions, including shipping companies, freight forwarders, and technology solution providers, whose experiences provide crucial insights regarding implementation challenges, success factors, and realized benefits. The third category included maritime business program coordinators, curriculum developers, and instructors from universities and maritime institutions responsible for educating future logistics professionals, whose perspectives illuminate current educational practices and constraints affecting curriculum modernization efforts. From these broader populations, the study employed purposive sampling to recruit seventy-two total participants distributed as forty-five logistics professionals completing structured surveys, twelve representatives from early adopter organizations participating in semi-structured interviews, and fifteen maritime business educators contributing to curriculum analysis and interviews regarding educational transformation challenges.

Logistics professional participants were recruited through Indonesian Logistics and Forwarders Association networks, LinkedIn professional groups focused on maritime logistics, and direct outreach to major shipping companies and freight forwarders operating in Indonesian ports. Selection criteria required participants to have minimum three years experience in roles involving international trade documentation, ensuring adequate familiarity with

current paper-based bill of lading processes to provide informed perspectives regarding digital alternatives. The forty-five logistics professional participants represented diverse organizational contexts including international container shipping lines, regional feeder operators, multinational freight forwarding companies, domestic forwarding SMEs, and cargo owner organizations with significant import-export activities, enabling capture of varying perspectives reflecting different market positions, organizational scales, and technological sophistication levels. Early adopter organization representatives were identified through industry publications reporting eBL implementations, platform provider client lists, and snowball sampling where initial interviewees recommended additional participants with relevant experiences. The twelve early adopter representatives included senior operations managers, digital transformation project leaders, and IT directors from organizations implementing various eBL platforms including WAVE, CargoX, essdocs, and TradeLens, providing insights spanning different technological solutions and implementation contexts. Maritime business educator participants were recruited from ten Indonesian universities and maritime institutions offering logistics, shipping management, or supply chain management programs, with selection criteria requiring direct responsibility for curriculum development or instruction in maritime trade, shipping operations, or logistics management courses where digital trade documentation would logically be incorporated.

The research employed three primary data collection instruments aligned with different participant categories and research objectives. The first instrument consisted of a structured questionnaire administered to logistics professionals, addressing five thematic domains representing key Technology Acceptance Model constructs and eBL-specific considerations. The questionnaire examined perceived usefulness through items addressing anticipated benefits including faster document processing, reduced operational costs, enhanced cargo visibility, decreased fraud risks, and improved letter of credit processing. Perceived ease of use was assessed through items addressing interface intuitiveness, integration with existing systems, technical complexity, and learning curve expectations. Trust mechanisms were evaluated through items examining data security confidence, platform reliability perceptions, legal enforceability beliefs, and concerns about system vulnerabilities. Regulatory clarity was measured through items addressing legal recognition confidence, jurisdiction-specific concerns, cross-border enforceability perceptions, and regulatory uncertainty impacts. Ecosystem readiness was assessed through items examining trading partner willingness perceptions, banking sector preparedness, customs

authority digital capability, and interoperability between platforms. Behavioral intention to adopt represented the dependent variable, measured through items indicating likelihood of organizational eBL implementation, willingness to advocate for adoption, and expected adoption timeframes. Each domain incorporated multiple indicators measured using five-point Likert scales enabling quantitative analysis of response patterns while open-ended questions captured qualitative elaborations and specific concerns.

The second research instrument consisted of semi-structured interview protocols designed for early adopter organization representatives, exploring implementation experiences, motivations, challenges encountered, solutions developed, and outcome assessments. Interview protocols addressed organizational decision-making processes leading to eBL adoption, specific platforms selected and rationale for choices, implementation timelines and phasing strategies, technical integration challenges and resolutions, organizational change management approaches, training programs developed for staff, trading partner onboarding experiences, cost-benefit realizations compared to expectations, ongoing operational considerations, and future plans for expanding eBL utilization. Interviews also explored participants' perspectives on industry-wide adoption barriers and potential acceleration strategies, providing insights extending beyond individual organizational experiences to broader ecosystem considerations. The third research instrument involved systematic curriculum analysis examining course syllabi, learning outcomes, assessment methods, and teaching materials from maritime business programs at participating institutions. Analysis protocols documented whether and how programs addressed blockchain technologies, digital trade documentation, eBL platforms specifically, smart contracts, supply chain digitalization, and related competencies, identifying presence, depth, and pedagogical approaches employed. Supplementary interviews with maritime business educators explored constraints affecting curriculum modernization including faculty expertise gaps, resource limitations, industry partnership challenges, and institutional approval processes for curriculum changes.

Data collection proceeded between February and September 2024, with surveys distributed electronically through professional networks and achieving 68% response rate from targeted logistics professionals. Early adopter interviews were conducted via video conference and in-person meetings, averaging seventy-five minutes duration and audio recorded with informed consent for subsequent transcription. Curriculum

analysis involved collection of syllabi and course materials from participating institutions supplemented by interviews with program coordinators exploring pedagogical rationales and modernization initiatives. All data collection adhered to research ethics protocols ensuring informed consent, confidentiality protection, and secure data management practices. Data analysis employed multiple analytical approaches suited to different data types and research objectives. Survey data received descriptive statistical analysis examining central tendencies, variation patterns, and correlation relationships among Technology Acceptance Model constructs, while thematic analysis of open-ended survey responses identified common themes in perceived benefits and concerns. Interview transcripts from early adopters underwent systematic thematic analysis following established qualitative methodology, with coding focused on identifying implementation success factors, challenge patterns, and outcome assessments. Cross-case comparison examined similarities and differences across organizations implementing different platforms or operating in distinct market segments. Curriculum analysis employed content analysis methodology systematically documenting digital trade documentation coverage across programs, identifying common gaps, and noting exemplar practices where institutions demonstrated stronger integration of emerging technologies. Narrative synthesis integrated findings across all data sources, developing coherent explanatory frameworks addressing research questions regarding adoption factors, educational gaps, and transformation pathways while maintaining grounding in empirical evidence and stakeholder perspectives [14].

3. RESULTS AND DISCUSSION

3.1 Results

The multi-method investigation yielded comprehensive insights regarding blockchain-based eBL adoption factors, implementation experiences, and maritime business education implications, organized into four major thematic domains: adoption intentions and influencing factors, implementation experiences and lessons learned, educational gap analysis, and curriculum modernization recommendations. Results demonstrated strong theoretical awareness of eBL benefits among logistics professionals yet revealed substantial concerns regarding practical implementation barriers, while curriculum analysis exposed significant disparities between rapid industry digitalization and limited academic preparation for digital trade documentation competencies.

Table 1: Technology Acceptance Factors and Adoption Intentions

TAM Construct / Factor	Mean Score (1-5)	Std. Dev	Positive Response (%)	Primary Concerns/Benefits
Perceived Usefulness	4.12	0.68	82%	Document processing speed (+), Cost reduction (+), Fraud prevention (+)
Faster document handling	4.45	0.62	91%	24-48 hour advantage vs. courier
Reduced operational costs	4.23	0.71	85%	Courier, printing, storage savings
Enhanced cargo visibility	4.18	0.75	83%	Real-time status tracking
Decreased fraud/disputes	4.02	0.79	78%	Immutable records, authentication
Improved LC processing	3.89	0.84	72%	Banking system integration needed
Trust Mechanisms	3.45	0.91	58%	Platform reliability (?), Legal enforceability (?), Cybersecurity (?)
Data security confidence	3.58	0.88	64%	Encryption, access controls adequate
Platform reliability	3.42	0.95	55%	New technology concerns persist
Legal enforceability	3.31	0.97	52%	Jurisdiction-specific uncertainty
System vulnerability concerns	3.48	0.89	59%	Blockchain immutability reassuring
Regulatory Clarity	3.22	1.02	48%	Legal recognition gaps, Cross-border uncertainty
Domestic legal recognition	3.45	0.98	58%	Some progress, gaps remain
International enforceability	3.08	1.05	42%	Rotterdam Rules limited adoption
Customs acceptance	3.35	0.94	54%	Pilot programs encouraging
Banking sector readiness	3.01	1.09	38%	Conservative approach evident
Ecosystem Readiness	3.18	0.97	45%	Trading partner willingness (?), Interoperability (?), Critical mass (?)
Trading partner willingness	3.28	0.92	51%	Coordination challenges significant
Platform interoperability	3.02	1.04	39%	Multiple platforms create confusion
Port authority capability	3.35	0.89	56%	Major ports advancing faster
Industry-wide coordination	3.07	1.01	41%	Chicken-and-egg dynamics
Adoption Intention	3.65	0.86	67%	Conditional interest dominant
Likelihood within 2 years	3.42	0.94	58%	"Wait and see" approach common
Willingness to advocate	3.71	0.82	71%	Support if barriers addressed
Expected organizational benefit	3.82	0.79	74%	ROI concerns manageable

Note: (+) indicates perceived benefit; (?) indicates concern area; Scale: 1=Strongly Disagree to 5=Strongly Agree

Analysis of survey responses revealed that logistics professionals demonstrated strong recognition of eBL potential benefits, with perceived usefulness scoring highest among Technology Acceptance Model constructs at mean 4.12 indicating agreement that blockchain-based eBL offers substantial operational advantages. Faster document handling received strongest endorsement (mean 4.45), with thirty-eight respondents explicitly noting that eliminating physical

document courier requirements could reduce port dwell time and accelerate cargo release by 24-48 hours in major container terminals. Cost reduction benefits (mean 4.23) were valued particularly by freight forwarders and smaller shipping companies that bear substantial documentation processing expenses under current paper-based systems. However, trust mechanisms (mean 3.45), regulatory clarity (mean 3.22), and ecosystem readiness (mean 3.18) scored significantly lower, indicating that despite recognized benefits, substantial concerns regarding implementation

feasibility and risk factors constrain adoption enthusiasm.

Qualitative analysis of open-ended survey responses and interview data revealed specific concerns underlying lower scores in trust, regulatory, and ecosystem domains. Legal enforceability emerged as particularly salient concern, with twenty-nine respondents expressing uncertainty regarding whether electronic bills of lading would be recognized as valid documents of title in disputes adjudicated by courts in various jurisdictions. Several participants cited specific cases where their organizations had encountered challenges with electronic documentation acceptance by customs authorities or banking institutions

unfamiliar with digital alternatives to paper originals. Platform interoperability concerns featured prominently, with respondents noting confusion regarding multiple competing eBL solutions and expressing reluctance to invest in platforms that might not achieve industry-wide acceptance or interoperate with trading partners' chosen solutions. Banking sector conservatism emerged as frequently mentioned barrier, with participants describing banks' reluctance to accept eBL for letter of credit processing despite technical capabilities, attributing this hesitation to risk aversion and regulatory uncertainty rather than technological limitations.

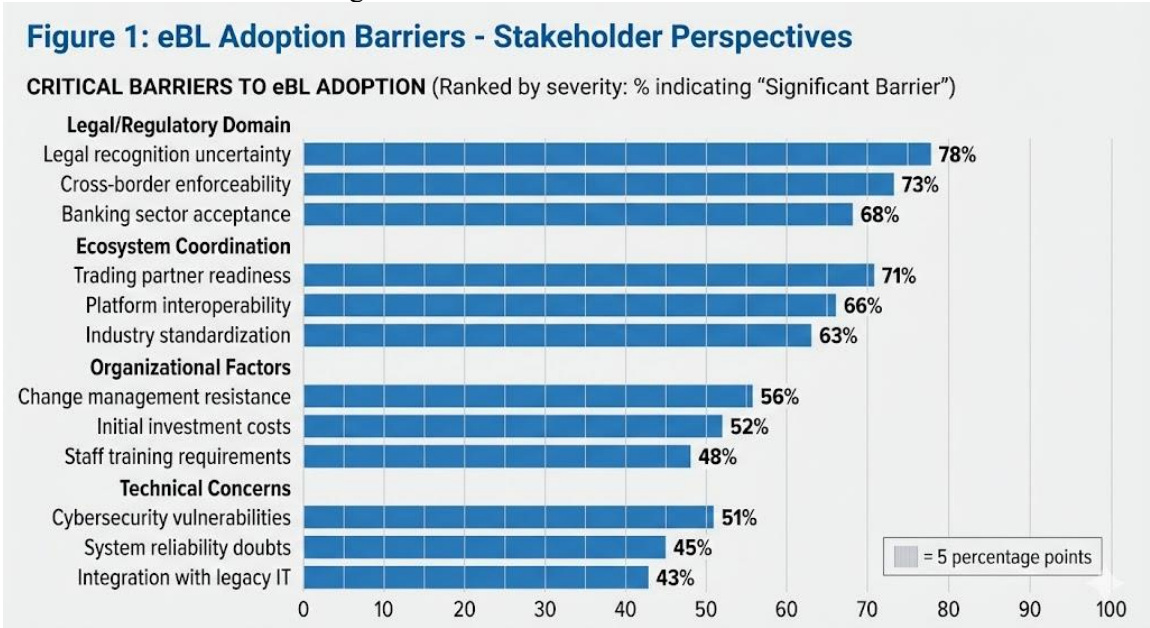


Figure 1: eBL Adoption Barriers - Stakeholder Perspectives

Early adopter interview findings provided valuable counterpoints to barrier perceptions while simultaneously validating certain concerns based on implementation experiences. Ten of twelve early adopter organizations reported achieving substantial operational benefits including 40-60% reduction in documentation processing time, elimination of courier costs averaging \$75-150 per shipment, and measurably faster cargo release enabling improved service offerings to customers. Several early adopters described competitive advantages gained through eBL capabilities, including ability to serve time-sensitive cargo segments, enhanced customer satisfaction scores, and differentiation in commodity shipping markets. However, early adopters also acknowledged significant

implementation challenges. Nine organizations reported that trading partner onboarding required substantially more effort than anticipated, with many partners initially reluctant to adopt new workflows despite potential benefits. Six organizations experienced integration difficulties connecting eBL platforms with existing enterprise resource planning systems and transport management systems, requiring custom development work and extended implementation timelines. Four organizations noted that banking sector reluctance to fully embrace eBL for trade finance purposes limited realized benefits, forcing maintenance of parallel paper processes for letter of credit transactions despite having digital bill of lading capabilities.

Table 2: Maritime Business Education Gap Analysis

Curriculum Component	Industry Importance (%)	Current Coverage (%)	Coverage Depth	Gap Severity
Blockchain fundamentals	85	23	Superficial	Critical
eBL platform operations	92	12	Minimal	Critical
Smart contract concepts	78	18	Theoretical only	Significant

Digital documentation workflows	88	35	Traditional focus	Significant
Trade finance digitalization	82	28	Limited fintech	Significant
Legal frameworks for eBL	90	15	Outdated materials	Critical
Cybersecurity in shipping	75	41	General coverage	Moderate
Platform evaluation criteria	68	8	Absent	Significant
Implementation change management	71	22	Generic only	Moderate
Industry ecosystem coordination	65	31	Traditional focus	Moderate

Coverage Depth: Comprehensive (>60% programs, substantial depth) / Moderate (40-60% programs, moderate depth) / Superficial (20-40% programs, limited depth) / Minimal (<20% programs, brief mention)

Maritime business education curriculum analysis revealed substantial gaps between industry digitalization trajectory and academic preparation. Only three of fifteen analyzed programs included dedicated coverage of blockchain technologies in maritime applications, with two of these representing brief guest lectures rather than integrated curriculum components. eBL platforms received explicit coverage in only two programs, both cases involving individual instructor initiatives rather than systematic curriculum integration. Twelve programs maintained traditional emphasis on paper bills of lading procedures, INCOTERMS, and conventional trade documentation without substantive

acknowledgment of digital alternatives. Interviews with maritime business educators illuminated multiple factors contributing to these gaps, including limited faculty expertise in blockchain technologies (thirteen of fifteen educators acknowledged having minimal understanding of distributed ledger systems), lack of teaching resources and case materials appropriate for maritime business contexts (eleven educators noted difficulty finding suitable materials beyond generic blockchain content), absence of industry partnerships providing access to actual eBL platforms for student hands-on experience (fourteen programs lacked any formal relationships with eBL platform providers), and institutional curriculum approval processes creating lag between industry change recognition and implemented curriculum modifications (nine educators described bureaucratic barriers delaying desired updates).

Figure 2: Proposed Maritime Business Education Modernization Framework

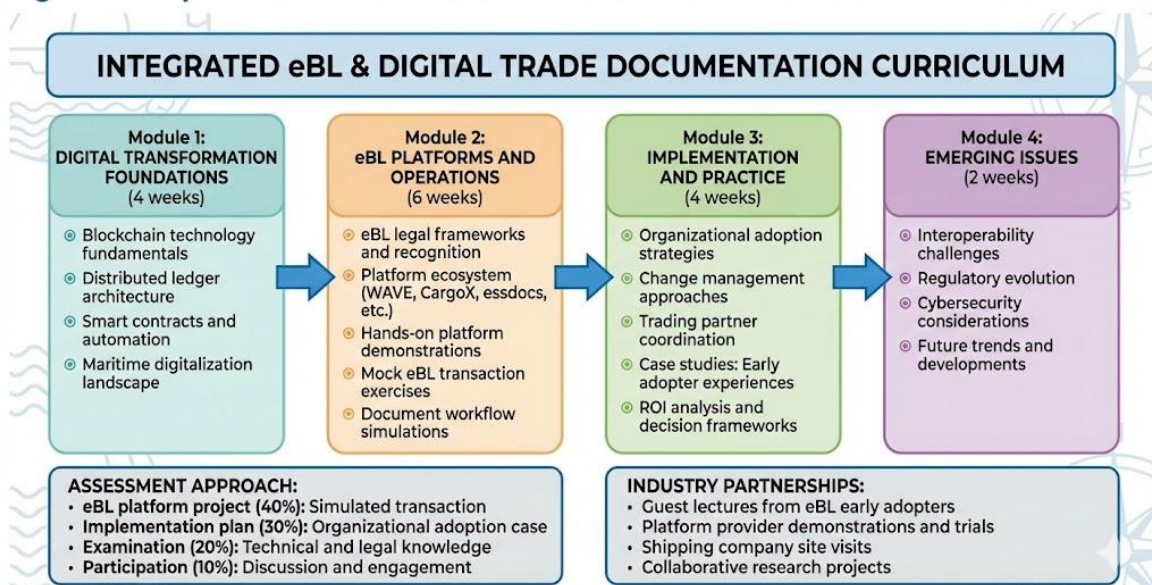


Figure 2: Proposed Maritime Business Education Modernization Framework

3.2 Discussion

The findings illuminate critical dynamics influencing blockchain-based eBL adoption while simultaneously exposing substantial maritime business education challenges that potentially constrain industry digital transformation capacity. The research results directly address central questions regarding adoption factors and educational implications, revealing complex

interplay between perceived benefits, implementation barriers, and workforce preparation gaps that collectively shape technology diffusion trajectories within maritime logistics ecosystems.

The strong endorsement of eBL perceived usefulness combined with substantially lower confidence regarding trust mechanisms, regulatory clarity, and ecosystem readiness validates and extends

Technology Acceptance Model applications within maritime technology contexts [15]. The findings align with prior research demonstrating that perceived usefulness alone proves insufficient for driving technology adoption when significant uncertainty regarding reliability, legal recognition, or ecosystem support exists [16]. The research contributes original empirical evidence quantifying the magnitude of these gaps within maritime documentation contexts, revealing that regulatory and ecosystem concerns represent more substantial adoption barriers than technical functionality or operational benefit questions. This pattern suggests that acceleration of eBL adoption requires coordinated interventions addressing legal frameworks, industry standards, and ecosystem coordination mechanisms rather than solely technology platform improvements.

The early adopter implementation experiences provide crucial insights extending beyond theoretical adoption models to practical realization of benefits and challenges. The finding that early adopters achieved substantial operational improvements yet encountered significant trading partner onboarding difficulties and banking sector resistance illustrates the systemic nature of digital trade documentation transformation, where individual organizational capabilities prove insufficient without corresponding ecosystem evolution. This finding resonates with innovation diffusion literature emphasizing the importance of complementary investments and institutional adaptations for successful technology implementation in network industries [17]. The research contributes practical understanding of specific implementation challenges including system integration complexities, workflow redesign requirements, and parallel process maintenance necessities that abstract adoption models typically overlook. These insights provide valuable guidance for prospective adopters planning eBL initiatives while simultaneously illuminating competency requirements for maritime logistics professionals who must navigate these implementation complexities.

The maritime business education gap analysis reveals concerning disparities between rapid industry digitalization and academic curriculum evolution, with implications extending beyond immediate graduate preparedness to broader innovation capacity constraints. The finding that fewer than one-quarter of analyzed programs provide any substantive coverage of blockchain technologies or eBL platforms, despite 85-92% of logistics professionals rating these as important knowledge domains, suggests systematic educational system lag that potentially perpetuates rather than resolves digital skills shortages. This pattern aligns with broader concerns in technical education literature regarding challenges maintaining curriculum currency amid rapid technological change [18]. However, the

research advances beyond general observations by documenting specific gaps, quantifying coverage deficiencies, and identifying root causes including faculty expertise limitations, resource constraints, and institutional process barriers that generic "keep curriculum current" recommendations inadequately address.

The educator perspectives revealing limited blockchain understanding, scarce teaching resources, and absence of industry partnerships illuminate systemic capacity constraints requiring coordinated responses beyond individual instructor initiative. This finding supports arguments that effective technical education transformation requires institutional-level strategic commitment, systematic faculty development programs, and formal industry-academia partnerships rather than relying on isolated innovative educators [19]. The research contributes practical understanding that maritime business education modernization for digital trade documentation competencies necessitates deliberate investment in faculty professional development, curriculum resource development, and platform provider partnerships enabling authentic learning experiences. The proposed modernization framework addresses these requirements through integrated approach combining foundational knowledge, hands-on platform experience, implementation case studies, and industry collaboration, offering actionable template for institutions pursuing curriculum enhancement.

The practical implications extend across multiple maritime education and industry stakeholder domains. For maritime business program administrators and curriculum developers, the research provides evidence-based rationale and concrete framework for curriculum modernization initiatives addressing documented gaps between industry requirements and current educational delivery. The modular structure accommodates implementation within existing course frameworks or as dedicated elective offerings, enabling phased adoption appropriate to institutional contexts and resource constraints. For faculty members, the framework offers structured content organization and pedagogical approach guidance supporting confident instruction even for those with limited prior blockchain or eBL expertise, particularly when combined with industry partnerships providing guest lectures and platform demonstrations. For prospective students and career advisors, the research illuminates emerging competency requirements in maritime logistics fields, supporting informed educational pathway selection and professional development planning. For shipping companies, freight forwarders, and logistics service providers, improved graduate preparation for digital trade documentation environments directly addresses workforce development challenges while potentially

accelerating organizational eBL adoption through availability of appropriately skilled personnel. For eBL platform providers, partnerships with maritime education institutions offer opportunities to cultivate future user communities, gather feedback supporting product development, and demonstrate social responsibility supporting industry workforce development.

The study's strengths include its integration of industry practice and educational perspectives enabling comprehensive understanding of adoption-education interdependencies, its multi-method approach combining quantitative adoption surveys with qualitative implementation experiences and systematic curriculum analysis, and its development of actionable recommendations grounded in stakeholder perspectives and documented gaps. The inclusion of early adopter experiences provides valuable real-world validation and nuancing of adoption factor assessments from non-adopter populations.

However, several limitations warrant acknowledgment. The study's geographical concentration in Indonesian and Southeast Asian contexts may limit generalizability to maritime ecosystems with different regulatory environments, technological infrastructures, or educational systems. The relatively small early adopter sample (n=12), while providing valuable insights, cannot support strong statistical inferences regarding implementation success factors or outcome variations across organizational types. The curriculum analysis, while systematic, relied on publicly available syllabi and educator interviews rather than direct classroom observation or student outcome assessment, potentially missing actual instructional practices differing from documented curricula. Future research employing experimental pedagogical evaluation comparing alternative teaching approaches for digital trade documentation, longitudinal tracking of graduate performance in digital logistics environments, and broader international comparative studies would provide valuable complementary evidence. Additionally, investigation of how regulatory evolution, platform standardization, and ecosystem maturation influence adoption trajectories over time would support more dynamic understanding of maritime digital transformation processes.

4. CONCLUSION

This research reveals that while maritime logistics professionals recognize substantial operational benefits of blockchain-based electronic bills of lading, significant concerns regarding legal recognition, ecosystem coordination, and interoperability constrain adoption enthusiasm. Early adopter experiences validate potential benefits while highlighting implementation challenges requiring coordinated

ecosystem responses extending beyond individual organizational capabilities. Maritime business education analysis exposes critical gaps between industry digitalization trajectory and academic curriculum coverage, with fewer than one-quarter of programs providing substantive blockchain or eBL instruction despite strong industry demand. The proposed integrated curriculum framework addresses identified gaps through structured progression from blockchain fundamentals through hands-on eBL platform experience to implementation case analysis, supported by industry partnerships enabling authentic learning. Effective maritime business education modernization requires institutional commitment to faculty development, curriculum resource investment, and formal industry collaboration, ultimately supporting both graduate employability and broader maritime digital transformation capacity.

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