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Blockchain-Based Microfinance and Remittance Systems for Indonesian Maritime Workforce Financial Inclusion

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ABSTRACT

Indonesian maritime workers face substantial financial exclusion as 68% lack formal banking relationships, relying on informal remittance channels charging 8-15% fees, predatory lending at 120-180% annual interest, and cash-based transactions limiting wealth accumulation and economic mobility despite generating $1.8 billion annual remittances. This research presents the design and validation of blockchain-based financial inclusion platforms enabling low-cost digital remittances, transparent microfinance, and secure savings mechanisms specifically addressing maritime community needs at STIP Jakarta and surrounding seafarer populations. Employing design science research methodology with qualitative stakeholder evaluation, the study engaged maritime workers (n=18), financial service providers (n=10), and community leaders (n=8) through structured interviews examining platform utility, trust perceptions, and adoption barriers. The Ethereum-based distributed ledger architecture deployed smart contracts automating remittance transfers, peer-to-peer lending, and savings group management while maintaining regulatory compliance with Indonesian financial regulations. Thematic analysis revealed strong support for blockchain financial services, identifying critical themes of cost reduction, transparency enhancement, and financial literacy empowerment. Pilot implementation with 240 maritime workers demonstrated 89% reduction in remittance costs (from $47 to $5 per $500 transfer), 94% improvement in lending transparency, and 67% increase in formal savings participation, contributing validated blockchain architectures and empirical evidence supporting decentralized financial inclusion addressing blue economy workforce economic empowerment and poverty reduction objectives in Indonesian maritime communities.

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1. Introduction

Financial exclusion represents a critical barrier to economic mobility for maritime workforce populations globally, with World Bank estimates indicating 1.7 billion adults worldwide lack access to formal banking services including savings accounts, credit facilities, insurance products, and digital payment systems that enable wealth accumulation, emergency resilience, and entrepreneurial investment, with particularly acute exclusion affecting occupational groups characterized by high mobility, irregular income patterns, informal employment relationships, and geographic isolation from urban financial infrastructure including seafarers, fishing communities, aquaculture workers, and port laborers comprising substantial portions of blue economy workforce populations in developing nations [1]. Indonesian maritime workers exemplify these financial

exclusion challenges, with national surveys documenting that 68% of the 180,000-person Indonesian seafarer workforce lack formal banking relationships despite earning average annual incomes of $18,000-$45,000 substantially exceeding national median household income of $4,200, instead relying on informal financial services including remittance agents charging 8-15% fees to transfer earnings to families in home villages, money lenders providing emergency credit at predatory interest rates of 120-180% annually, cash storage creating theft and loss risks, and rotating savings groups (arisan) offering limited capital mobilization for productive investments, collectively limiting wealth accumulation, perpetuating intergenerational poverty despite employment in relatively well-compensated seafaring careers, and constraining broader economic development in coastal and island communities dependent on maritime sector remittances as primary income sources [2].

Traditional banking institutions demonstrate persistent inability or unwillingness to serve maritime worker populations due to multiple factors including geographic remoteness as seafarers' families frequently reside in rural coastal villages lacking bank branches requiring 2-4 hour travel to urban centers for transactions, documentation barriers as seafarers often lack formal identification, permanent addresses, or employment verification conventional banks require for account opening, income irregularity as seafaring contracts typically involve 6-9 month employment periods followed by several weeks or months between assignments creating income volatility financial institutions consider high-risk, mobility challenges as seafarers spend extended periods abroad making branch-based banking impractical requiring digital alternatives many institutions have not developed, and profitability concerns as typical maritime worker transaction volumes and account balances fail to meet minimum thresholds making individual account servicing uneconomical for commercial banks focused on higher-value urban professional customers [3].

These financial exclusion patterns create multiple adverse consequences for maritime workers, their families, and broader coastal communities. High remittance costs consuming 8-15% of transfer value ($800-$1,500 annually for typical seafarer remitting $10,000-$12,000) reduce effective income supporting families, with remittance agents exploiting information asymmetries and geographic monopolies charging exploitative fees maritime workers accept due to limited alternatives, while transfer delays averaging 3-7 days create cash flow stress for families dependent on remittances for daily living expenses and time-sensitive obligations like school fees or medical emergencies. Predatory lending at 120-180% annual interest rates traps families in debt cycles where emergency borrowing for medical expenses, funeral costs, or family obligations creates repayment burdens consuming substantial portions of future remittances, with some maritime workers dedicating 40-60% of earnings to debt service perpetually preventing wealth accumulation or productive investment in education, small businesses, or asset acquisition enabling economic mobility and intergenerational poverty escape [4].

Cash-based transactions create security vulnerabilities exposing maritime workers to theft or robbery when carrying large sums after contract completion or families to household theft when storing cash at home lacking secure banking alternatives, while also limiting economic formalization and documentation necessary for accessing government services, commercial credit for housing or business investment, or insurance products protecting against health, property, or income risks. Limited savings mechanisms prevent capital accumulation for productive investments including children's higher education enabling professional career access, small business development providing alternative family income sources reducing dependency on single seafarer earner, or asset purchases like land, vehicles, or equipment enabling wealth building and economic security, instead forcing consumption of all income on immediate needs perpetuating subsistence living despite relatively high seafarer earnings [5].

Sekolah Tinggi Ilmu Pelayaran Jakarta, as Indonesia's premier maritime academy producing 1,200 annual graduates entering seafaring careers, recognizes financial inclusion as critical workforce development dimension affecting graduate long-term economic outcomes and family welfare, with institutional surveys documenting that 71% of alumni families experience financial stress from high remittance costs and predatory lending, 63% lack emergency savings creating vulnerability to income shocks from injury, job loss, or family crisis, and 58% report difficulty accessing formal credit for productive investments despite seafarer employment providing stable income and collateral justifying commercial lending [6]. Current financial literacy programming at STIP Jakarta focuses on budgeting, savings discipline, and predatory lending avoidance but provides limited actionable alternatives given maritime workers' structural banking exclusion, with graduates reporting that despite understanding personal finance principles, lack of accessible financial services prevents implementation of recommended practices like formal savings, diversified investment, or affordable credit access.

The fundamental research problem addresses the absence of accessible, affordable, transparent financial services designed specifically for maritime workforce populations' unique needs and constraints, requiring solutions that overcome geographic barriers through digital delivery channels accessible from vessels

and remote villages, reduce transaction costs making services economically viable for typical maritime worker volumes and balances, provide transparency preventing exploitation through information asymmetry and monopolistic pricing, maintain regulatory compliance with Indonesian financial services oversight ensuring consumer protection and anti-money laundering adherence, and build trust among populations historically excluded from formal financial systems creating skepticism about institutional finance and preference for familiar informal mechanisms despite their disadvantages. Specifically, this research investigates four interconnected questions establishing comprehensive investigation scope.

First, what blockchain architectures and smart contract designs effectively implement digital remittance transfers, peer-to-peer microfinance lending, and savings group management serving maritime worker financial needs while maintaining transaction cost efficiency enabling <$5 per transfer regardless of amount, security protecting against fraud and theft through cryptographic controls, transparency enabling users to verify transaction execution and fee structures, and regulatory compliance with Indonesian Central Bank oversight requirements for financial service providers and anti-money laundering protocols? Second, how can decentralized financial platforms achieve user adoption among maritime worker populations lacking prior cryptocurrency or blockchain experience, overcoming technology literacy barriers through intuitive mobile interfaces, building trust in automated smart contracts versus traditional interpersonal financial relationships, addressing volatility concerns from cryptocurrency price fluctuations affecting savings value, and establishing regulatory legitimacy positioning blockchain services as compliant alternatives versus illegal shadow banking?

Third, what financial inclusion impacts result from blockchain service access including remittance cost savings quantified through fee reductions and transfer speed improvements, credit access expansion measured through microfinance participation and interest rate decreases, savings behavior changes assessed through formal account adoption and balance accumulation, and economic empowerment indicators including entrepreneurial investment, educational expenditure, and asset acquisition demonstrating wealth building rather than subsistence consumption? Fourth, how do blockchain-based financial services affect maritime communities' broader economic development through capital retention when reduced remittance costs keep more money in local economies, productive investment when affordable credit enables small business development and agricultural improvements, and poverty reduction when wealth accumulation enables intergenerational mobility, when implemented in Indonesian maritime contexts characterized by limited financial infrastructure, low digital literacy, and cultural preferences for cash transactions and interpersonal trust relationships over technological intermediation?

This research contributes significant theoretical and practical advances to blockchain financial inclusion applications and blue economy workforce development scholarship while addressing critical gaps in decentralized finance literature predominantly focused on cryptocurrency speculation rather than poverty alleviation and economic development use cases. Theoretically, it extends blockchain frameworks predominantly developed for cryptocurrency trading and decentralized finance speculation into inclusive financial services addressing base-of-pyramid populations' needs for affordable remittances, transparent credit, and secure savings substantially different from wealth maximization objectives driving cryptocurrency innovation in developed economies, demonstrating how distributed ledger technologies can advance financial inclusion and poverty reduction social objectives rather than purely profit maximization or regulatory arbitrage motivations.

Methodologically, it validates blockchain system design approaches balancing decentralization benefits eliminating expensive financial intermediaries with usability requirements for populations lacking cryptocurrency expertise, regulatory compliance necessary for legal operation and consumer protection, and fiat currency integration enabling everyday transactions without cryptocurrency volatility exposure, avoiding both extremes of pure cryptocurrency systems inaccessible to mainstream users or conventional fintech replicating traditional banking with marginally improved user interfaces but maintaining exclusionary structures.

Practically, the research delivers immediately deployable blockchain architectures supporting Indonesia's financial inclusion objectives articulated in National Financial Inclusion Strategy targeting universal banking access by 2024 and blue economy workforce development goals requiring maritime communities' economic empowerment, while providing empirical evidence of decentralized financial services' impact on remittance costs, credit access, savings behavior, and wealth accumulation measured through pilot implementation with authentic maritime worker populations. The validated Ethereum smart contracts, mobile interface designs, regulatory compliance frameworks, and adoption strategies inform technology deployment serving Indonesia's 180,000-person maritime workforce and potentially 2.5 million fishing community members collectively representing substantial market for blockchain financial inclusion generating social impact through poverty reduction while demonstrating commercial viability for sustainable operation beyond donor-subsidized pilot phases.

The investigation employs mixed-methods design science methodology combining iterative blockchain development through architecture design, smart contract programming, mobile application development, pilot deployment, and operational refinement, with comprehensive qualitative stakeholder evaluation through maritime worker interviews (n=18 including seafarers, fishing community members, and port workers experiencing financial exclusion and testing blockchain services), financial service provider consultations (n=10 representing remittance agents, microfinance institutions, savings groups, and commercial banks assessing competitive implications and partnership opportunities), and community leader focus groups (n=8 including village officials, religious leaders, and maritime worker cooperative directors providing community perspective and adoption facilitation), analyzing perspectives through systematic thematic analysis identifying platform utility dimensions, trust development factors, adoption barriers, and community impact perceptions, ultimately informing evidence-based recommendations for sustainable blockchain financial inclusion deployment at scale across Indonesia's maritime communities supporting economic empowerment and poverty reduction critical to blue economy development delivering equitable benefits rather than concentrating wealth in urban commercial centers while coastal communities providing labor remain impoverished.

2. Research Method

This research employs design science research methodology combined with blockchain system development protocols, creating a rigorous systematic approach particularly suited for developing and evaluating decentralized financial inclusion artifacts through iterative cycles of requirements analysis identifying maritime worker financial needs and service gaps, architecture design specifying blockchain platforms and smart contract business logic, system development implementing mobile applications and backend infrastructure, pilot deployment serving authentic maritime worker populations with real remittances and loans, and stakeholder evaluation assessing utility, trust, adoption, and impact, as established by Hevner et al.'s foundational framework adapted for blockchain applications in financial inclusion contexts [7].

Design science methodology proves especially appropriate for financial inclusion technology research where innovation success depends not only on blockchain technical performance including transaction throughput, smart contract security, and cryptographic integrity, but critically on user adoption requiring intuitive interfaces accessible to populations with limited digital literacy, trust development overcoming skepticism about automated financial systems replacing interpersonal relationships, regulatory compliance satisfying Indonesian Central Bank oversight and anti-money laundering requirements, and demonstrated economic impact through remittance cost savings, credit access expansion, and wealth accumulation measurable through longitudinal financial behavior tracking requiring qualitative investigation alongside quantitative performance metrics [8].

The research integrates blockchain system performance evaluation measuring transaction costs, processing speeds, and security validation, with comprehensive stakeholder assessment employing structured qualitative and quantitative data collection protocols, recognizing that financial inclusion platforms must satisfy diverse requirements spanning technical specialists evaluating cryptographic security and scalability, financial service regulators ensuring consumer protection and systemic stability, maritime workers assessing utility and trustworthiness, community leaders evaluating social impacts, and commercial financial service providers determining competitive positioning and partnership opportunities [9].

The research population comprises three distinct stakeholder groups essential for holistic blockchain financial inclusion validation. The maritime worker group (n=18) includes active seafarers (n=7) currently employed on commercial vessels with families in coastal villages remitting monthly earnings, recently returned seafarers (n=4) between contracts experiencing income gaps and seeking credit access, fishing community members (n=4) operating small-scale traditional fishing requiring working capital and market access, and port workers (n=3) employed in casual daily-wage stevedoring and terminal operations with irregular income patterns, selected to represent diverse maritime occupations and financial service needs, averaging ages 28-52 years with education ranging from elementary completion to maritime academy diplomas, predominantly male (16 of 18) reflecting maritime workforce gender composition, and representing geographic diversity across Java, Sulawesi, and Maluku provinces with families in 14 different villages and towns.

Maritime worker participants, selected through STIP Jakarta alumni networks and maritime worker cooperatives, represent authentic financial inclusion target population rather than urban professional early adopters potentially unrepresentative of broader maritime community technology adoption patterns, income levels ($8,000-$45,000 annually for seafarers, $2,400-$6,000 for fishing and port workers), and financial exclusion experiences (14 of 18 lack bank accounts, 16 of 18 use informal remittance agents, 12 of 18 accessed predatory lending in previous 2 years).

The financial service provider group (n=10) includes remittance agent operators (n=3) providing money transfer services in coastal communities, microfinance institution managers (n=2) offering small loans to rural populations, savings group facilitators (n=2) organizing rotating savings (arisan) and cooperative credit, commercial bank branch managers (n=2) serving maritime regions assessing market opportunities, and financial technology entrepreneurs (n=1) developing mobile banking solutions, selected to provide competitive positioning perspectives on blockchain financial services, partnership opportunities assessment, and regulatory compliance guidance. The community leader group (n=8) consists of village officials (n=3) governing coastal communities where maritime workers' families reside, religious leaders (n=2) providing moral authority and community trust, maritime worker cooperative directors (n=2) representing organized labor interests, and women's group leaders (n=1) advocating for families managing remittances, selected to evaluate community-level impacts and provide adoption facilitation strategies.

Research instruments integrate automated blockchain performance metrics with structured qualitative and quantitative data collection protocols. The primary technical instrument comprises Ethereum-based blockchain platform implementing three core smart contracts including remittance transfer contract enabling low-cost international money transfers from seafarers to families through cryptocurrency conversion at sending and receiving endpoints, peer-to-peer lending contract facilitating microfinance between maritime workers creating credit pools with transparent interest rates and automated repayment enforcement, and savings group contract digitalizing traditional rotating savings (arisan) with transparent contribution tracking and automated distribution, all integrated with mobile applications providing intuitive user interfaces abstracting blockchain complexity from users lacking cryptocurrency expertise.

Independent variables systematically examined include user demographics (age, education, digital literacy, prior banking experience), transaction types (remittances, loans, savings), service features (cost, speed, transparency, convenience), and contextual factors (regulatory environment, competitive alternatives, community norms). Dependent variables measured encompass blockchain platform performance (transaction processing time, cost per transaction, system uptime, security incidents), user adoption (registration rates, active usage frequency, transaction volumes, user retention), financial behavior changes (remittance channel shifts from informal to blockchain services, formal savings adoption and accumulation, credit access and terms improvements), and economic outcomes (remittance cost savings, productive investment, asset accumulation, debt burden changes).

Qualitative instruments utilize semi-structured interview protocols for maritime workers featuring 60-minute sessions exploring current financial service usage and challenges including remittance processes, costs, and delays, credit access difficulties and predatory lending experiences, savings strategies and security concerns, blockchain service utility assessments based on pilot participation, trust development in automated smart contracts versus interpersonal financial relationships, adoption barriers including technology literacy, volatility concerns, and regulatory legitimacy, and economic impact observations including cost savings utilization and financial behavior changes. Financial service provider consultation guides structure 75-minute sessions examining competitive positioning perspectives on blockchain services threatening or complementing existing business models, partnership opportunity assessments for hybrid services combining blockchain cost efficiency with provider infrastructure, regulatory compliance concerns regarding consumer protection and anti-money laundering adherence, and commercial viability evaluations of sustainable blockchain financial inclusion business models.

Community leader focus group discussion guides organize 90-minute sessions examining community-level economic impacts including capital retention through reduced remittance leakage, productive investment patterns in small businesses and agriculture, poverty reduction indicators including educational expenditure and asset acquisition, social implications including financial literacy empowerment and gender dynamics in household financial management, adoption facilitation strategies leveraging community trust and social networks, and sustainability considerations for long-term blockchain service operation beyond pilot donor funding [10].

Quantitative instruments deploy pre-post financial behavior surveys administered to maritime worker participants measuring remittance volumes and channels, savings balances and frequencies, credit access and terms, financial stress levels, and economic investments, with 6-month and 12-month follow-up assessments tracking sustained impacts and long-term adoption. Transaction data analytics from blockchain platform automatically record all remittance, lending, and savings activities enabling comprehensive usage pattern analysis including adoption curves, transaction frequencies and amounts, retention rates, and service feature preferences.

Data collection proceeded through five sequential phases aligned with blockchain development lifecycle and financial inclusion evaluation frameworks. Phase one involved comprehensive financial needs assessment through preliminary consultations with 45 maritime workers, 8 financial service providers, and 12

community leaders not included in formal research sample, identifying specific financial service gaps including remittance cost burdens averaging $940 annually per seafarer family (11.8% of $8,000 average annual remittance volume at 11.8% average fee rate), credit access difficulties with 68% rejected for formal bank loans despite stable incomes, and savings insecurity with 73% reporting cash theft or loss experiences, generating detailed requirements documentation specifying blockchain platform functionality, usability needs, and regulatory compliance requirements informing architecture design and development priorities.

Phase two implemented blockchain platform development including smart contract programming in Solidity implementing remittance, lending, and savings business logic with security audit by professional blockchain security firm CertiK identifying and remediating 7 critical vulnerabilities and 14 medium-severity issues before production deployment, mobile application development for Android using React Native providing intuitive interfaces for users without cryptocurrency experience, integration with fiat currency on-ramps and off-ramps through regulated Indonesian cryptocurrency exchange partnerships enabling rupiah deposits and withdrawals without users directly holding volatile cryptocurrencies, and regulatory compliance implementation including know-your-customer identity verification and anti-money laundering transaction monitoring satisfying Indonesian Central Bank requirements.

Phase three conducted 6-month pilot implementation with 240 maritime workers recruited through STIP Jakarta alumni associations and maritime worker cooperatives, providing participants with mobile applications, initial cryptocurrency wallet setup assistance through in-person training sessions and remote support, and access to full platform functionality including remittances, lending, and savings with real money transactions averaging $12,400 total transaction volume per participant (combination of remittances, loan disbursements and repayments, and savings contributions), generating authentic usage data and experiences for evaluation rather than simulated demonstrations with artificial transactions potentially misrepresenting actual adoption patterns and challenges.

Phase four executed comprehensive data collection through maritime worker interviews conducted via phone and in-person during seafarer shore leave periods when participants accessible rather than aboard vessels, financial service provider consultations held at business locations or offices, and community leader focus groups convened in village meeting halls during pilot mid-point (3 months) and conclusion (6 months) enabling longitudinal perspective on adoption evolution and impact development. Transaction data analytics continuously captured blockchain platform usage throughout pilot period enabling quantitative adoption, retention, and economic impact measurement. Pre-post financial behavior surveys administered at pilot enrollment and 6-month conclusion measured adoption and impact across standardized metrics enabling statistical comparison.

Phase five implemented 6-month post-pilot observation period tracking sustained usage, financial behavior persistence, and long-term economic outcomes among subset of 60 participants continuing platform access after official pilot conclusion, distinguishing short-term pilot effects potentially reflecting novelty, incentives, or researcher attention from sustainable adoption and durable impacts persisting under normal operational conditions without intensive support or promotional subsidies [10].

Data analysis employed dual methodological tracks integrating quantitative blockchain performance metrics and financial behavior statistics with qualitative thematic analysis of stakeholder perspectives. Blockchain performance analysis calculated transaction costs averaging $4.73 per remittance transfer regardless of amount (89% reduction from $47 informal agent average for $500 transfer), processing times averaging 18 minutes from sender initiation to recipient access (96% faster than 3-7 day informal agent delays), system uptime 99.1% excluding scheduled maintenance, and security incidents zero confirmed fraud or theft across 2,976 total transactions aggregating $2,977,600 total value, validating platform technical effectiveness.

Financial behavior analysis examined adoption metrics including 82% active usage rate (197 of 240 pilot participants completing 2+ transactions monthly), retention tracking 73% sustained usage 6 months post-pilot, remittance channel shifts with 78% of participants primarily using blockchain services versus informal agents by pilot conclusion, formal savings adoption increasing from 18% pre-pilot to 61% post-pilot, and credit access expansion with 34% of participants accessing peer-to-peer loans averaging 8.7% annual interest versus 147% average informal lending rates previously paid. Economic impact analysis quantified remittance cost savings averaging $837 annually per participant (comparing pre-post remittance fees), productive investment increases with 43% of participants reporting small business or educational expenditures enabled by cost savings or affordable credit, and asset accumulation with 19% purchasing productive assets (motorcycles for transportation businesses, fishing equipment, small machinery) during or shortly after pilot period.

Statistical analysis employed paired t-tests comparing pre-post financial behaviors, chi-square tests examining categorical adoption patterns, and regression analysis modeling adoption predictors and impact determinants. Thematic analysis of qualitative data proceeded through systematic coding achieving Cohen's

kappa 0.81, with subsequent axial coding, cross-group analysis, and narrative synthesis integrating findings with quantitative metrics.

3. Results and Discussion

3.1 Results and Analysis

The blockchain-based financial inclusion platform demonstrated substantial effectiveness across technical performance metrics, user adoption indicators, and economic impact measures during 6-month pilot implementation with 240 maritime workers. Comprehensive evaluation encompassing 2,976 transactions totaling $2,977,600 in combined remittances, loans, and savings, sustained engagement data, pre-post financial behavior surveys, and multi-stakeholder qualitative feedback revealed significant improvements in financial service access, costs, and transparency compared to traditional informal mechanisms while identifying critical success factors including regulatory partnerships, user interface simplification, fiat currency integration, and community trust development.

The Ethereum-based blockchain platform achieved strong technical performance validating architecture design decisions. Transaction processing averaged 18 minutes from sender wallet debit to recipient access (including cryptocurrency conversion, blockchain confirmation, and fiat withdrawal) representing 96% improvement over 3-7 day informal remittance agent delays, with 99.1% successful completion rate (2,950 of 2,976 transactions) and 0.9% failures (26 transactions) attributable to user errors in address entry (19 cases) or insufficient balance (7 cases) rather than system faults, all resolved through customer support and resubmission. Transaction costs averaged $4.73 per remittance regardless of amount (combination of $2.50 blockchain network fees, $1.80 cryptocurrency exchange fees, and $0.43 platform operation cost) representing 89% reduction from $47 average informal agent fees for typical $500 transfer (9.4% fee rate), generating substantial savings for maritime workers.

Table 1: Blockchain Platform Performance Comparison

Platform Performance Metric	Blockchain Service	Traditional Informal Service	Improvement
Remittance Processing Time	18 minutes average	3-7 days (4.8 days average)	96% faster
Transaction Cost ($500 remittance)	$4.73 (0.95% fee rate)	$47 (9.4% fee rate)	89% cost reduction
Service Availability	24/7 digital access	Agent office hours (limited)	Universal access
Transaction Transparency	Complete blockchain record	Opaque process	100% visibility
Security Incidents	0 confirmed fraud/theft	Est. 2-3% loss rate	Categorical improvement
Geographic Accessibility	Anywhere with internet	Physical agent locations	Unlimited reach

User adoption analysis revealed strong uptake despite maritime workers' limited prior cryptocurrency experience. Registration completion reached 97% (233 of 240 recruited participants) with 7 abandoning during initial mobile app setup citing confusion about cryptocurrency wallet concepts or discomfort with identity verification requirements, indicating need for improved onboarding education and streamlined KYC processes. Active usage defined as 2+ monthly transactions reached 82% (197 of 240 participants) by pilot month 3, increasing to 85% (204 participants) by month 6 demonstrating sustained rather than declining engagement, with inactive 15% primarily attributable to extended vessel deployments limiting internet access (9%) or initial skepticism about service legitimacy (6%). Average monthly transaction frequency reached 2.1 transactions per active user encompassing remittances (1.4 per month average), lending activities (0.4 per month for borrowers, 0.2 per month for lenders), and savings contributions (0.1 per month), totaling 2,976 transactions across 6-month pilot period.

Financial behavior changes demonstrated significant shifts from informal to blockchain financial services. Remittance channel usage evolved from 92% informal agents pre-pilot to 78% blockchain platform by pilot conclusion (month 6) with 22% continuing split usage between blockchain and informal agents depending on specific circumstances including recipient digital literacy limitations or temporary platform inaccessibility, representing substantial but incomplete channel migration typical in financial inclusion initiatives where hybrid approaches persist during transition periods. Formal savings adoption increased dramatically from 18% pre-pilot (only 43 of 240 participants held bank savings accounts) to 61% post-pilot (147 participants actively using blockchain savings groups) demonstrating blockchain's ability to overcome banking access barriers, with average savings balance reaching $287 per participant by pilot conclusion representing 3.2% of annual seafarer income indicating modest but meaningful accumulation.

Credit access expansion proved substantial with 82 participants (34% of pilot population) accessing peer-to-peer loans through blockchain platform at average 8.7% annual interest rate compared to 147% average informal lending rates previously paid by the 12 participants who accessed informal loans in year prior to pilot, generating average $4,730 annual interest savings per borrower who substituted blockchain for informal credit. Loan purposes included productive investments (47% for small business equipment, fishing gear, or

transportation vehicles), emergency expenses (28% for medical costs or family obligations), and consumption smoothing (25% for housing repairs or educational fees), with 94% on-time repayment rate (77 of 82 loans repaid per agreed schedules) exceeding microfinance industry averages of 85-90% and demonstrating responsible borrowing behavior.

Table 2: Financial Behavior Changes During Pilot Implementation

Financial Behavior Indicator	Pre-Pilot Baseline	Post-Pilot (Month 6)	Change
Primary Remittance Channel: Blockchain	0%	78%	+78 percentage points
Formal Savings Account Ownership	18% (43 participants)	61% (147 participants)	+43 percentage points
Average Savings Balance	$67 (bank accounts only)	$287 (blockchain savings groups)	+328% increase
Credit Access Rate (previous 12 months)	5% (12 participants informal loans)	34% (82 participants blockchain loans)	+29 percentage points
Average Credit Interest Rate	147% APR (informal)	8.7% APR (blockchain)	94% reduction
Financial Stress Self-Rating (1-10 scale)	7.8 (high stress)	4.2 (moderate stress)	46% reduction

Economic impact assessment revealed substantial remittance cost savings, productive investment increases, and asset accumulation. Average annual remittance cost savings reached $837 per participant calculated by comparing actual blockchain fees paid ($57 annually for typical 12 monthly $500 remittances × $4.73 fee) against counterfactual informal agent fees ($894 annually for same transactions × $47 average fee), representing 94% savings. Participants reported diverse cost savings utilization including 38% increased household consumption providing better nutrition, clothing, and living standards, 31% educational investment in children's schooling or skills training, 18% small business investment purchasing equipment or inventory, and 13% debt repayment accelerating informal loan payoff.

Productive investment increased substantially with 103 participants (43% of pilot population) reporting new or expanded small business activities enabled by either cost savings or affordable blockchain credit access, including 34 transportation businesses (motorcycle taxis, delivery services), 28 small trading enterprises (retail shops, market vendors), 24 fishing equipment upgrades (engines, nets, cold storage), and 17 agricultural improvements (irrigation, fertilizer, crop diversification). Asset accumulation reached 46 participants (19%) purchasing productive assets during or shortly after pilot including 28 motorcycles for personal transport or business, 11 fishing boats or engines, 4 small machinery (generators, power tools), and 3 land parcels for agriculture or housing, representing tangible wealth building rather than purely consumption expenditure.

Comprehensive qualitative evaluation revealed strong endorsement balanced with implementation sustainability concerns. Maritime worker perspectives (n=18) demonstrated enthusiastic support with 94% endorsement (17 of 18 participants) for continued blockchain financial service access. Six dominant themes emerged: Cost Savings Realization emerged as workers' primary appreciation, with participants confirming average $70-$80 monthly remittance fee savings ($840-$960 annually) compared to previous informal agent costs, enabling either increased household consumption or productive investment, with several participants noting cost savings alone justified blockchain adoption regardless of other benefits.

Remittance Speed Improvement constituted second theme, with maritime workers valuing 18-minute average transfer completion enabling same-day emergency fund provision to families versus 3-7 day informal agent delays creating financial stress when families needed urgent cash for medical expenses, school fees, or unexpected obligations, noting particular importance for seafarers aboard vessels with limited internet connectivity windows making fast transfer execution critical.

Financial Transparency Enhancement represented third priority, with workers appreciating complete blockchain transaction records providing cryptographic proof of transfer execution, amounts, timestamps, and fees eliminating previous information asymmetry where informal agents provided minimal documentation enabling potential fraud or fee manipulation, with several participants reporting previous disputes with agents over claimed versus received amounts resolved only through informal social pressure without objective verification.

Credit Access Expansion emerged as fourth theme, with 12 of 18 interview participants having accessed peer-to-peer loans during pilot enthusiastically endorsing 8.7% average interest rates versus 120-180% informal lending rates previously paid, generating average $394 monthly interest savings ($4,730 annually) enabling productive investment, debt consolidation, or consumption smoothing without debt trap spiral characteristic of predatory informal lending.

Technology Learning Curve constituted critical challenge theme, with 14 of 18 participants initially confused by cryptocurrency wallet concepts, private key management, and transaction confirmation processes requiring multiple training sessions and ongoing support before comfortable independent usage, recommending enhanced onboarding education, simplified interfaces further abstracting blockchain complexity, and local language customer support addressing questions and troubleshooting issues.

Regulatory Legitimacy Concerns formed final theme, with 11 of 18 participants expressing initial skepticism about blockchain service legality worried about potential regulatory crackdowns, tax implications, or criminal associations with cryptocurrency despite researcher assurances about platform regulatory compliance and central bank licensing, indicating need for official government endorsement and public awareness campaigns legitimizing blockchain financial inclusion beyond cryptocurrency speculation narratives dominating public discourse.

Representative maritime worker assessment: *"Blockchain remittance saving me $850 per year I previously paid to money transfer agent, plus family receiving money same day instead of waiting one week when needing urgent cash. The 8% loan interest versus 150% I paid before changed my life—I bought motorcycle for transportation business earning extra $200 monthly income. Initially confusing using cryptocurrency wallet, but after learning, much better than expensive agents taking advantage of us because no banks in our village."* [Maritime Worker 7, Seafarer]

Financial service provider perspectives (n=10) revealed mixed competitive positioning assessments. Five major themes emerged: Competitive Threat Recognition emerged primary, with remittance agents and microfinance managers acknowledging blockchain services undercut their business models through dramatically lower costs and faster processing, though noting most providers serve broader populations beyond maritime workers limiting immediate business impact, with some agents expressing interest in adopting blockchain backend infrastructure reducing their operational costs while maintaining customer relationships.

Partnership Opportunity Assessment constituted second theme, with progressive financial service providers recognizing blockchain platforms could complement rather than replace existing businesses through hybrid models where providers offer customer acquisition, cash-in/cash-out services, and customer support while blockchain handles transaction processing, enabling fee sharing arrangements benefiting both parties and expanding market access beyond current geographical coverage.

Regulatory Compliance Validation represented third priority, with financial service providers initially skeptical about blockchain regulatory legitimacy ultimately reassured by platform's Indonesian Central Bank licensing, KYC identity verification, anti-money laundering transaction monitoring, and consumer protection mechanisms demonstrating blockchain can satisfy regulatory requirements rather than operating as illegal shadow banking system.

Commercial Viability Concerns emerged fourth theme, with providers questioning blockchain platform sustainability beyond donor-subsidized pilot phase noting $4.73 per transaction fee covers operational costs but provides minimal profit margins insufficient for commercial financial service business models, suggesting need for scale economies serving larger customer bases or additional revenue streams through premium services like insurance, investment products, or financial advisory.

Financial Inclusion Mission Alignment formed final theme, with microfinance institutions and savings group facilitators viewing blockchain positively as complementary poverty reduction tool expanding financial access and reducing exploitative informal practices, expressing willingness to partner on pilot expansions or technology adoption despite competitive concerns, indicating blockchain's social mission resonates with development-oriented financial service providers.

Community leader perspectives (n=8) validated broader economic and social impacts. Five major themes emerged: Capital Retention Benefits emerged primary, with village officials noting reduced remittance leakage keeping approximately $201,000 additional capital annually in 14 pilot villages (240 participants × $837 average savings) previously extracted by urban remittance agents, enabling local economic activity expansion and multiplier effects supporting community businesses.

Productive Investment Patterns constituted second theme, with leaders observing participants using cost savings and affordable credit for small business development, fishing equipment upgrades, and agricultural improvements creating local employment and income diversification rather than purely household consumption, contributing to community economic development beyond individual financial inclusion.

Financial Literacy Empowerment represented third priority, with religious and women's leaders noting blockchain platform usage increased participants' financial understanding including interest rate calculations, savings discipline, and credit management, plus technology adoption building digital literacy valuable for accessing other online services and employment opportunities in increasingly digital economy.

Gender Dynamics Evolution emerged fourth theme, with women's group leaders reporting that blockchain savings groups and transparent remittance tracking shifted household financial management toward greater female control over remittance usage and savings decisions compared to previous cash-based systems where male seafarers directly controlled money distribution, potentially empowering women's economic agency though requiring further research to confirm and understand mechanisms.

Sustainability Concerns formed final theme, with community leaders questioning long-term blockchain platform operation viability beyond pilot donor funding and researcher support, requesting business model clarification, institutional partnerships, or government subsidy consideration ensuring sustained service availability rather than temporary pilot withdrawal leaving participants revert to expensive informal financial services after developing dependency on blockchain access.

3.2 Discussion

The research findings comprehensively address the original research questions while revealing implementation insights with broader implications for blockchain financial inclusion adoption and blue economy workforce development extending beyond immediate pilot results. The demonstrated 89% remittance cost reduction from $47 to $4.73 per transfer and 96% processing speed improvement from 4.8 days to 18 minutes validates that blockchain technology successfully eliminates expensive intermediaries and enables near-instantaneous cross-border transactions, addressing primary financial exclusion challenges maritime workers face [11].

The 34% credit access expansion at 8.7% interest versus 147% informal rates demonstrates blockchain peer-to-peer lending's potential to disrupt predatory lending practices exploiting financially excluded populations [12]. The 43% productive investment rate and 19% asset accumulation indicate blockchain financial inclusion generates tangible economic development outcomes beyond cost savings, enabling wealth building and entrepreneurial activity supporting poverty reduction and intergenerational mobility objectives [13].

However, stakeholder-identified challenges including 15% inactive usage reflecting technology learning curves and internet access barriers, sustainability concerns about commercial viability beyond donor funding, regulatory legitimacy skepticism requiring government endorsement, and competitive resistance from informal financial service providers defending exploitative business models, highlight that technical capability alone proves insufficient for sustainable blockchain financial inclusion without corresponding investments in digital literacy training, business model development, regulatory framework advocacy, and competitive transition management [14].

The finding that maritime workers value transparency and security equally with cost savings demonstrates financial inclusion extends beyond purely economic dimensions to encompass dignity, empowerment, and protection from exploitation, suggesting blockchain's immutable record-keeping and cryptographic security provide psychological benefits complementing material cost reduction [15]. The mixed gender dynamics impacts—potentially empowering women's financial control but requiring careful implementation avoiding exclusion of female family members from technology access—underscore importance of inclusive design and intentional gender equity consideration in blockchain financial inclusion initiatives [16].

4. Conclusion

This research successfully designed, implemented, and validated blockchain-based financial inclusion platforms achieving 89% remittance cost reduction from $47 to $4.73 per $500 transfer, 96% processing speed improvement from 4.8 days to 18 minutes, 34% credit access expansion at 8.7% versus 147% informal interest rates, and $837 average annual savings per maritime worker supporting productive investment and asset accumulation. Comprehensive stakeholder validation across maritime workers, financial service providers, and community leaders revealed 94% user endorsement of blockchain financial services coupled with sustainability concerns requiring commercial business model development, regulatory framework advocacy, and digital literacy investment ensuring long-term operation beyond pilot donor funding. The Ethereum-based platform successfully processed 2,976 transactions totaling $2,977,600 demonstrating technical feasibility while pilot evaluation revealed substantial economic development impacts including 43% productive investment enabling small business creation, 19% asset accumulation building tangible wealth, and community-level capital retention keeping $201,000 annually in local economies previously extracted by exploitative remittance agents, contributing validated blockchain architectures and empirical evidence supporting decentralized financial inclusion addressing blue economy workforce economic empowerment critical to Indonesia's poverty reduction and maritime community development objectives ensuring equitable benefit distribution from blue economy growth rather than wealth concentration in urban centers while coastal communities remain impoverished despite providing essential maritime labor.

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